STUDENT'S MANUAL

OF

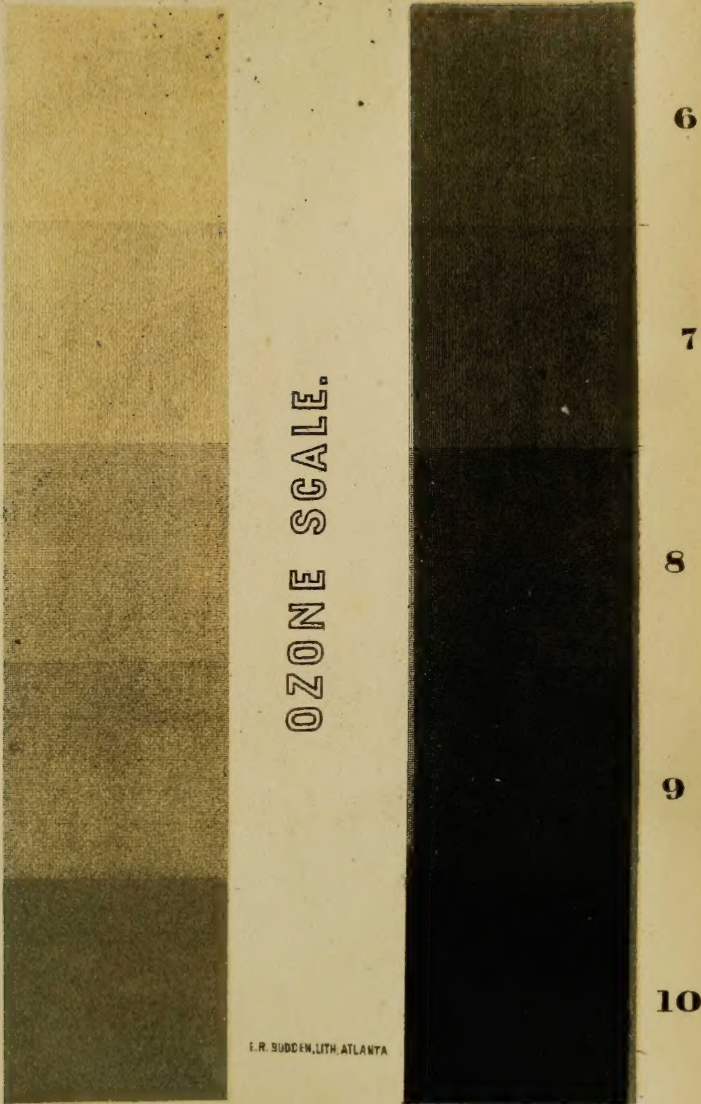
CHEMICO-PHYSICS.

AND

METEOROLOGY.

LOGAN.

To Gov. Brown
From the Author.



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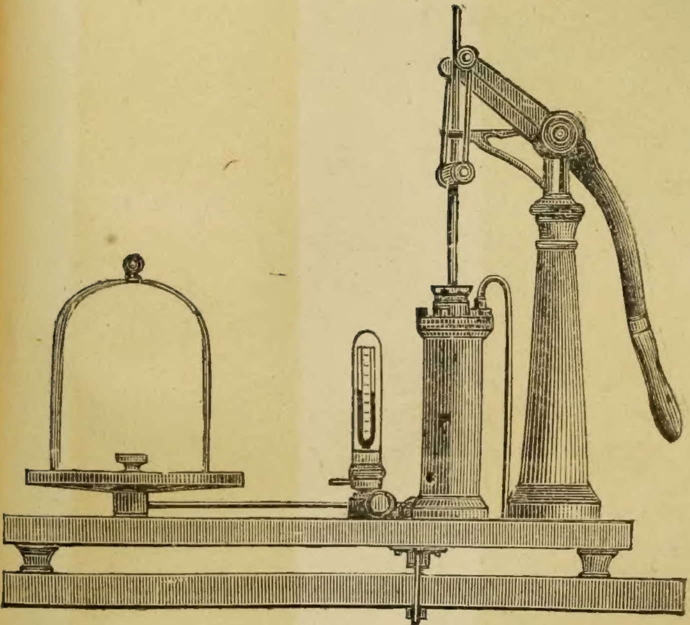

STUDENT'S MANUAL

OF

CHEMICO-PHYSICS

IN

THREE PARTS,

BY

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"*Omne enim Manifestatum, lumen est.*"—PAUL.

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PART FIRST.

CHEMICO-PHYSICS, WITH METEOROLOGY AND METRICAL SYSTEM OF WEIGHTS AND MEASUBES.

PART SECOND.

A MANUAL OF GENERAL, MEDICAL, AND HYGENIC CHEMISTRY INORGANIC.

IN PREPARATION.

PREFACE.

IN this Manual, the Student will find the important subjects treated, so condensed and simplified as to make it an easy task to master them, even in the brief time usually allotted to such studies. He will find here, a differentiation, precise as possible, of Chemistry, from Natural Science; also, the Theory and Leading Principles clearly and concisely defined of Heat, Light, Electricity and Magnetism, both as a distinctive science, and as related to Chemistry, Medicine, Hygiene and Practical Life. He will find the general Theory of Weights and Measures, the English System with the Art and Forms of Prescribing according to its standard, the Metrical System and the Art and Methods of Prescribing and Dispensing by that standard, both so explained and presented as to be comprehended at once by any one who really desires their acquisition.

Lastly, he will find a practical view of the deeply interesing subject of Meteorology in its present advanced development, and rapidly progressing claims upon the Scientist, the Sanitarian and Physician.

The author acknowledges his indebtedness to the excellent works of Fownes, Youmans, Roscoe, Barker, Rockwell, Mann, the American Metrical Bureau, the State Board of Health of Michigan, and especially to the courtesy of Hall & Benjamin, manufacturers of Scientific supplies, New York.

ATLANTA, GA., January 1st, 1880.

SCIENCE.

Physics, Chemistry and Natural History.

What is Science?

Science is digested, classified knowledge of the properties, structure and elementary principles of things.

How May Science be Conveniently Divided?

Into three great departments, viz: Physics, Chemistry and Natural History.

What is Natural History?

It is that branch of knowledge which considers only the form and internal structure of bodies.

What is Physics?

It is that branch of knowledge which treats of the properties of matter, whether in mass or molecular division. It is, therefore, properly divided into molar and molecular physics; the first embracing Mechanics, Hydrostatics, Hydraulics, and Pneumatics; and the second, Heat, Light and Electricity.

What is Chemistry?

Chemistry, since it too treats of the properties of matter, may in that sense, be allied to the Physical Sciences. It considers the properties of the ultimate division of matter—the atom, and lies between Physics proper and Biology, reposing upon the first and supporting the latter.

What is Biology?

In its comprehensive sense, Biology is vegetable and animal Physiology.

What is Matter?

It is anything visible or tangible; anything which occupies space.

How is Matter Divided?

Into three forms—Solid, Liquid and Æriform.

What three Disvisions does Physics make in the Study of Matter?

It treats—

First—Of the DIVISIONS of which matter is capable.

Second—Of the attractions of its particles.

Third—Of the motions of which its particles are believed to be capable.

What are these Divisions of Matter?

There are three—Masses, Molecules and Atoms.

What is Mass Matter?

A mass is anything which can be appreciated by the senses.

What is a Molecule?

It is the smallest part into which a body can be divided without loss of idenity.

What is an Atom?

It is a particle more minute than the Molecule; it is the smallest portion of matter which can enter into chemical combination.

What makes up the Molecule?

A collection of atoms.

What are the Attractions of Matter?

There are three forms of attraction—

First—Gravitation, or the attraction of masses.

Second—Cohesion, or the attraction of mole-

cules. If the molecules be unlike, it is called Adhesive attraction.

Third—Chemical Attraction, or the attraction of atoms.

What are the Motions of Matter?

There are three forms—

First—The Motion of Mass, or Mechanical Motion.

Second—Molecular Motion, or the motion of the molecules in the mass. This motion in its variety of forms or conditions, constitutes the physical forces, Heat, Light, Electricity, and doubtless what is called vital force.

Third—Atomic Motion, or the motion of the atoms, if there be such a motion.

Do Molecules Differ?

Molecules must differ from each other, because they are composed of different atoms. These atoms may differ in KIND, in NUMBER or in their RELATIVE POSITION in the molecule. This is illustrated by a molecule of salt, and one of water, compared in regard to KIND of atoms; and a molecule of calomel and corrosive sublimate as regards the NUMBER of their atoms; and a molecule of starch compared with one of gum in respect to the ARRANGEMENT of their atoms.

What is Chemistry?

Chemistry is that branch of Physical Science which treats of the atomic composition of bodies, and of those changes in matter which result from an alteration in the KIND, the NUMBER or the RELATIVE POSITION of the atoms which compose the molecule.*

What are Physical Properties of Matter?

*Frankland.

They are the properties which matter possesses in virtue of its molecular constitution.

What are the Chemical Properties of Matter?

They are the properties which matter posseses in virtue of its atomic composition. Physical Phenomena take place outside the molecule; Chemical Phenomena inside the molecule among the atoms.

How many kinds of Molecules are there?

There are two; the ELEMENTAL MOLECULE, whose atoms are all alike, and the compound molecule, whose atoms are unlike.

Does not this fact divide all matter into two great classes?

It divides all matter into elemental bodies and compound bodies.

What is an Element?

It is a substance which can not be decomposed into simpler substances by any known process—it is uncompounded.

What is a Compound Substance?

It is a body made up by the union of two or more unlike elements.

How many Elements are known?

The number of the elements is sixty-four.

Are all the Elements equally important?

Many of them are rare and mere curiosities: only thirty-four are essential to the Student of Medicine.

Name these thirty-four Elements?

They are Hydrogen, Oxygen, Nitrogen, Chlorine, Sulphur, Selenium, Phosphorus, Carbon, Boron, Aluminum, Manganese, Iodine, Fluorine, Bromine, Barium, Lead, Iron, Silver, Tin, Zinc, Cobalt, Arsenic, Magnesium, Platinum, Nickel, Copper, Chromium, Strontium, Calcium,

Potassium, Sodium, Bismuth, Mercury and Antimony.

What are the Molecular or Physical Forces?

They are Heat, Light, Electricity and Magnetism.

HEAT.

Under what Heads may Heat be considered?

First—The Expansive Force of heat.

Second—The Conduction of heat.

Third—The Sources of heat.

Fourth—Change of Molecular condition or State by heat.

Fifth—Specific Heat.

Sixth—The New or Dynamical Theory of heat.

What is the first effect of Heat upon all substances?

It expands them; solids least and gases most of the three states of matter.

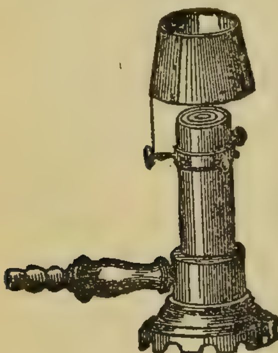


Fig. 2.—Erlenmeyer's New Form Burner.

Are not the Forms of all bodies fixed by Heat?

All bodies are either solid, liquid or gaseous, because of heat.

What then are the three most obvious Effects of Heat?

They are Expansion, Liquifaction and Vaporization.

What bodies will Heat most expand?

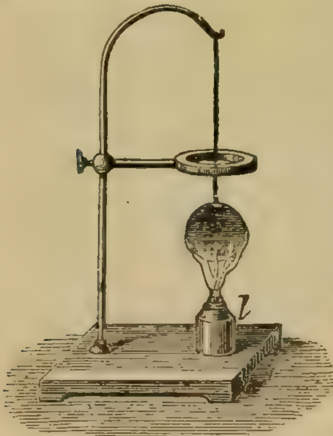


Fig. 3.—Ball and Ring.

It will expand most those bodies, whose molecules are least controlled by the attraction of cohesion; that is all gases.

Is this Force of Expansion very great?

It is one of the irresistible forces of nature.

Does Water Expand and Contract uniformly by Heat or its abstraction?

As its temperature approaches 0°C from 4°C or 39 F., it gradually expands; though it uniformly contracted down to 4°C, which is the point of the MAXIMUM DENSITY of water. From 0°C to 100°C water expands $\frac{1}{22}$ of its volume; alcohol $\frac{1}{9}$; and mercury [illegible]; water freezes at 0°C or 32°F.

Explain Figure 3.

The ball while cold passes easily through the ring, but expanded by heat it rents on the ring.

How does Expansion become the measure of Temperature?

Expansion is the effect of heat, therefore, the measurement of expansion will be the measure of the force of its cause.

What is the usual instrument for this purpose called?

It is called Thermometer or heat measurer. The expanding substance is a liquid and commonly mercury.

What two Thermometers are chiefly in use?

Fahrenheit's and the Centigrade. The first

is generally used in England and America ; the latter in France and by all scientists. The scale of F. is divided into 180 parts ; that of C into 100—that is, the space between the freezing and boiling points of water. Therefore, the F. scale is to the C as 180 is to 100, that is as 9 is to 5.

What is the Rule for changing F readings into those of C's ?

If the reading to be changed is F, subtract from it 32, multiply the remainder by 5, and divide the product by 9. If the reading be C, first multiply by 9, and divide the product by 5, adding 32 to the quotient. If either reading be NEGATIVE or from below zero of the scale, it is only necessary to apply the algebraic rules for such quantities, that is, that minus multiplied by plus gives minus, and a larger plus quantity subtracted from a less negative, gives a plus or positive remainder and vice versa. Example—

$20°C \times \frac{9}{5} + 32 = 68° F.$

What are the limits of range of the Mercurial Thermometer?

It can not indicate temperature as low as 40°C, nor higher than about 350°C, because mercury freezes at the first point and boils at the latter.

What fluid is used instead of mercury for lower temperatures than—40° C, and what Instrument for higher temperatures than 350° C ?

Colored alcohol is used for the lower temperatures, because no known degree of cold completely freezes it. An instrument called the Pyrometer, FIRE MEASURER, is in use for the higher.

What is the Clinical Thermometer ?

It is an instrument, more frequently used by physicians, to ascertain the temperature of the body in disease, the normal temperature being 98°

or 99° Fahrenheit. Itshould be self-registering.

How is this instrument applied?

After the patient has rested about an hour in bed, the bulb of the thermometer is placed deep within the axilla, the arm of the patient being folded across the breast. The instrument should remain in this situation five or ten minutes, and the indication must be noted before it is removed, if it be not self-registering.

Are the teachings of the Clinical Thermometer important?

This instrument has been but a short time in use by the medical profession, and has already established certain laws of temperature in disease, which are of great value.

What are the most important of these Laws?

First—That in fevers and other acute diseases, the temperature of the body is raised above the normal standard.

Second—That if the thermometer in the axilla does not indicate a temperature above 98° or 99° F., there is no fever present.

Third—That the range of increase of heat in different febrile diseases extends to 110° F., the amount of increase being a criterion of the intensity of the disease. The increase to 100° or 101° is evidence of a mild invasion. If the thermometer indicate persistently 105° it is certain that the attack is severe. A temperature of one or more degrees above 105° indicates great danger, and if it rise to 109° or 110° F., death is sure to follow.

Fourth—That whatever may be the other symptoms of a disease, its force is not abated, so long as the thermometer indicates increase of temperature.

Fifth—That a progressive increase of heat,

from day to day, denotes a corresponding increase in the severity of the disease, while a gradual reduction of heat to the normal standard, DEFERVESCENCE it is called, indicates convalescence.

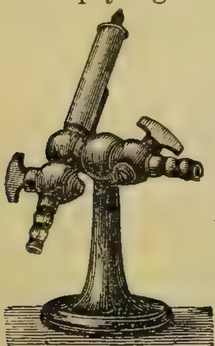
Sixth—That in some diseases, especially Typhoid fever, there is oscillation of temperature between night and morning, the maximum at night and the minimum in the morning, so that the thermometer most be used at least twice a day.*

What is Bunsen's Burner ?

It is a simple contrivance by which atmospheric air is burned with gas. thus producing an intensity of heat, which the gas alone is incapable of doing.

Describe Bunsen's Burner.

It is a metalic tube, resting at its lowest extremity upon a box, whose sides and bottom are pierced with several holes by which gas and air are admitted before reaching the flame above. The air may be admitted or shut out at pleasure. The instrument may be constructed so as to consist of two or more tubes combined, thus multiplying its power.



What instrument is represented in Figure 18 ?

This is Bunsen's Blast Lamp or Burner. It is adjusted so as to have universal motion, and is an instrument of great power. The principle of its action is readily understood.

*See Flint's Practice of Medicine, page 107.

What is Liquifaction?

It is the conversion of a solid into a liquid by the agency of heat.

What is Vaporization?

It is the conversion of a liquid into a vapor by the agency of heat.

What is Evaporation?

Evaporation is slow vaporization, general and spontaneous, at ordinary temperatures.

What is Condensation?

It is the abstraction of so much heat from a vapor, as to restore it to the state of a liquid.

What is Ebullition?

It is violent vaporization, produced by the rapid formation and rising of steam bubbles from the bottom of a heated vessel.

What is the Boiling Point?

It is the point at which any liquid begins to vaporize rapidly or violently. Liquids differ in this respect; so that a liquid's boiling point is one of its important characteristics.

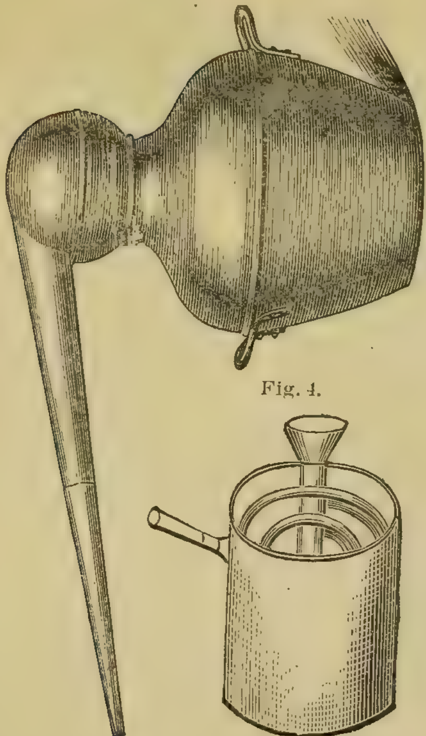


Fig. 4.

What is Distillation?

The distillation of a liquid, is vaporizing it in one vessel by heat, and condensing it by cold in another. In this way liquids are often separated from each other, as well as purified. See fig. 4.

What is the Fusion or Melting Point of Solids?

It is the point at which any solid body passes, by the agency of heat into a fluid. The melting point of solids, is also one of their im-

portant characteristics. In the case of a single metal, iron, another very important property is that it SOFTENS before fusing.

What is Sensible Heat?

It is the heat that may be indicated by the thermometer.

What is Latent Heat?

It is the heat which disappears, or is lost by any solid or liquid, in passing the one into a fluid and the other into a vapor. This is called the heat of fluidity. Any fluid contains more heat than any solid, and any vapor more than any liquid.

What is the Cryophorus?

It is an instrument designed to illustrate the cooling power of the process of evaporation. The name is derived from the Greek—KRUOS, ice and PHERO, I bear.

Describe the Cryophorus.

It consists of a tube, having a bulb of glass at each extremity. The air is first expelled from the instrument by boiling a little water contained in one of the bulbs, and sealing the opening through which it escaped, while the tube is full of vapor. If the empty bulb be now placed in a freezing mixture, the vapor condenses and produccs so rapid an evaporation from the water that it instantly freezes. (See fig. 5.)

This Latent Heat lies hid, but is it lost?

No; it is insensible, because it has been converted into something else—into an equivalent of mechanical work. It is this work or force that maintains the substance in its fluid or

gaseous state; a condition of potential energy.

May this Mechanical force among the molecules be re-converted into Heat, thus restoring it all again?

When any liquid becomes a solid again, or any vapor a liquid, the exact numerical equivalent of the heat, which had been converted, is restored and may be indicated by the thermometer.

What simple experiment proves this loss or conversion of Heat?

1 lb. of water at 32°F. 1 lb. of water at 174.2°F.	=2 lbs. of water at 103.1°,
1 lb. of water at 174.2°F. 1 lb. of ice at 32°F.	=2 lbs. of water at 32°, but the ICE IS MELTED.

The first mixture gives a mere mean of the two; the second, shows a loss of 142,2° which were consumed in MELTING THE ICE.

In the first mixture, the result is only the mean of the two temperatures. In the second, it is a loss of 142.2°, obviously consumed in melting a weight of ice equal to that of the water; that is a quantity which would raise one pound of water through a range of 142.2° F.

The sudden increase in volume, exhibited by water in the act of freezing, whose force is so enormous, has no relation, whatever, to the gradual expansion of pure water below 4° C. to 0° C.

What are the Laws relating to the Expansion of Gases?

First—All gases and vapors expand nearly alike for equal increments of heat.

Second—The rate of expansion is not altered by an increase or diminution of pressure.

Third—The rate of expansion is uniform for all degrees of heat.

Fourth—The constant increment of expansion for every degree above 0° C. is expressed by the fraction $\frac{1}{273}$ of its volume, or which is more convenient for calculations, $\frac{11}{3000}$.

What is Mariotte's Law?

The volume of any gas is inversely, and its density directly as the pressure to which it is subjected.

What is meant by the Density of a Gas?

It is the weight of a given volume of gas, as compared to an equal volume of hydrogen. Its SPECIFIC GRAVITY would be the same volume compared to an equal volume of air.

How may the Specific Gravity of any gas be obtained?

The specific gravity of hydrogen is 0.0693; this number multiplied upon the density of any gas must give its specific gravity. Hence it follows, that density may be obtained by dividing specific gravity by 0.0693.

Whet is a Heat-Unit?

The heat of combustion is measured by heat-units; a heat-unit being the quantity of heat required to raise 15.43 grains, or one gram of water from 0° C. to 1° C. Since one gram or 15.43 grains of carbon, burning in oxygen, gives 8080 units of heat, it would raise as many grams of water through the same number of degrees. Knowing the amount of carbon in any given fuel, it is easy to calculate its heat-giving value.

What is Joule's Law expressing the Mechanical Equivalent of Heat?

The quantity of heat required to raise one pound of water 1° F. will evolve a force adequate to raise a mass of 772 pounds one foot high, or of one pound 772 feet high.

These, by way of distinction, are called "FOOT POUNDS."

This law, therefore, is based upon the effect of ONE UNIT OF HEAT.

What is the Elastic Force of a Gas?

The force with which a vapor or gas expands is called its elastic force or tension. One cubic inch of water will expand by heat into nearly one cubic foot of vapor or steam.

What is Specifiic Heat?

All substances have not the same readiness to be raised by heat through 1° F. or any other range of the thermometric scale; they all differ in this respect, each one having its own capacity for heat; this is its SPECIFIC HEAT, and the measure of it is the quantity of heat, compared with that of water required to raise it through 1° F. that is one heat-unit.

What is the highest Specific Heat known?

That of hydrogen gas is the highest known to science. Water possesses the next highest capacity, and is the unit of measure for all specific heat. Water being 1, the specific heat of hydrogen is 3.409, and air being 1, the specific heat of hydrogen is 14.451. The specific heat of all other substances, is of course, expressed fractionally.

In how many ways is Heat communicated?

In three—by conduction, when it passes from particle to particle of the heating body; by convection, as when heat is conveyed by particles moving from one part of the heating substance to another; by radiation as when heat darts, as it were, through some portion of space from a hot body to a cold one.

What bodies are the best conductors?

Dense, solid bodies such as the metals.

Are liquids good conductors?

They are almost non-conductors.

Are Gases and Vapors good conductors?

Æriform bodies are yet worse conductors than liquids, air being about the worst conductor of them all. All fluids, embracing under that term both liquids and æriform bodies, are heated chiefly by convection.

How does Radiant Heat move?

It moves in straight lines from object to object, and is by these either REFLECTED, ABSORBED, or TRANSMITTED. The law of its reflection, is that the angle of reflection is always equal to that of incidence Good absorbers are poor reflectors, and *vice versa*. Heat in passing through most substances, is more or less intercepted or retained. The heat of the sun, however, passes through transparent substances without loss; but heat from the earth is in great part arrested, especially by such substances as water, alum and glass. This fact is very important.

What are the Sources of Heat?

They are five; the sun, the interior of the earth, Electricity, mechanical action and chemical action. The greatest of these is the sun.

How is Chemical Action a Source of heat?

When substances have their original constitutions broken up or altered, by being combined chemically with other substances, more or less heat is evolved; this is the heat of chemical action; it is also the same as that called the heat of vital action.

What is the Heat of Mechanical Action?

Heat and mass motion are always convertible one into the other, as by the friction of two solid or liquid bodies. This is the heat of mechanical action.

What is the Theory of Heat existing in the Interior of the Earth?

There are good reasons for believing that the interior of the earth from a depth of some fifty miles from its surface to the centre, is in a state of fusion.

How is Electricity the Source of Heat?

Electricity, like heat, is convertible alike into mechanical motion, chemical action and heat.

What is Heat?

It is now defined according to the dynamical theory, to be a mode of motion of the molecules. Intensity of this motion is the measure of temperature. Of the nature of heat nothing is known.

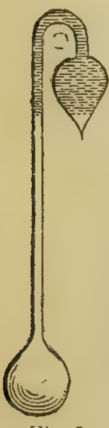


Fig. 5.

What is Dew?

It is the moisture of the air condensed upon bodies, with which it is in contact, colder than itself. It is a product of radiation.

What is meant by the Dew Point?

The temperature of the air at which condensation of its moisture takes place, is the DEW POINT. This point is constantly varying. Frost is frozen dew. Clouds are partially condensed vapor in the higher regions of the atmosphere. Fog and mist are condensed vapor at the earth's surface. Evaporation takes place from the surface of

bodies only, and depends, in great degree, upon the stillness, dryness, temperature and density of the atmosphere.

What is the Tension of a Vapor?

It is the force, expressed in inches of the barometer,* with which a vapor according to temperature, resists atmospheric pressure. The tention of water at 0°C, or 32°F. is 0.20 inches of the barometer; at 82°C or 180°F. it is 15.15 inches, and at 100°C. or 212°F. it is 30.00 inches of the barometer.

Does Air absorb moisture at all temperatures?

It does, and retains it in an invisible state. The higher the temperature the greater this power. Air is said to be saturated with moisture, when it contains as much as it can hold with a given temperature. The air usully contains from fifty to seventy per cent. of the saturating quantity of moisture. If the quantity be not within these limits, the air is disagreeably dry or moist.

How is the quantity of Moisture in the Air with any temperature ascertained?

By an instrument called the Hygrometer. Daniell's is the best in use.

What is the action of this Hygrometer?

The condensation is produced by the evaporation of ether. It is thus constructed: A glass tube being bent twice at right angles, having a long and short arm, each terminating in a bulb, the bulb of the short arm is wrapped in a piece of muslin, and that of the long arm half-filled with ether, into which a delicate thermometer dips. On the stand of the instrument is adjus-

*This instrument will be described in another place.

ted another thermometer to show the temperature of the air.

How is an observation made with it?

First pour a little ether upon the muslin wrapper; its evaporation quickly lowers the temperature of the other bulb, and when it reaches the dew point, a film of moisture is seen upon its surface. The thermometer in the tube indicates the temperature of this deposition, and fixes the dew point. But this observation merely shows the dew point to be high or low.

Can not the observation be extended so as to ascertain the absolute amount of moisture in a given volume of air?

It can, and its importance to the student requires a particular explanation of principles and practical details

We know that the vapor of water or steam, at 212° F. under a pressure of 30 inches of the barometer, is 1,700 times lighter than an equal volume of water at its maximum density of 40° F. Now a cubic foot of water, at that temperature weighs 437,272 grains; therefore, the weight of a cu. foot of steam, at the same temperature and pressure, is 437,272 : 1,700=257.-218 grains. Hence under Boyle's law,—density is directly as the pressure—it is easy to calculate the weight of the same volume of steam of the same temperature under any other given pressure.

Suppose the reading of the dew-point thermometer is 50° F. it is desired to know what is the amount of moisture in a cubic foot of air at this temperature?

Obviously the elasticity of the watery vapor, present, corresponds to a maximum density indicated by 50°, and according to a table of great

value, prepared by Dalton, it supports a barometric column of 0.400 inches. It follows, that 30: .400::257.218=3.426 grains of watery vapor at 212° and 30 in. weighs 257.218 grains, an equal volume of vapor, of the same temperature, supporting a column of 0.400 in. will weigh 3.426 grains.

But now what will it weigh at the given temperature of 50°?

This brings us to the rule of reducing gaseous volumes for temperatue, according to Gay Lussac's Law: "All gases expand or contract, by the same amount for the same increase or dimunition of temperature." The amount of this increase or contraction is $\frac{1}{460}$ of its volume for every degree of Fahrenheits thermometer from 32°. Hence, taking a volume of gas at 32° as unity, its volume at 50° is to its volume at 212° as $1+\frac{18}{460} : 1+\frac{180}{460}$.

The denominator, 18 is derived from 50°—32° and 180 from 212—32 The expression $1+\frac{18}{460}$ simplified is, 1, 0391, and $1+\frac{180}{460}$, is 1,375. Hence 50:212::1,0391:1,375, or 1,0391:1,375::3.426=4.534 grains, since it was just seen that a volume of air at 212° and 0.400 inches tension would weigh 3.426 grains.

How is all this calculation simplified, and made practically easy?

The above is a demonstration of the principle of these observations; but Dalton's table of gaseous tension for temperature with the corresponding results in grains per cubic foot of vapor, saves the trouble of repeated calculations, It should be copied by the pupil, and pasted up for convenient reference:

Temperature.	Elastic Tension.	Weight of Cubic Foot.
0°	.068 inches.	8.856 grains.
5	.083 "	1.034 "
10	.098 "	1.208 "
15	.119 "	1.451 "
20	·140 "	1 688 "
25	.170 "	2.228 "
30	.200 "	2.361 "
35	.240 "	2.805 "
40	.280 "	3.239 "
45	.340 "	3.893 "
50	.400 "	4.534 "
55	.476 "	5.342 "
60	.560 "	6.222 "
65	.657 "	7 230 "
70	.770 "	8.392 "
75	.906 "	9.780 "
80	1.060 "	11.333 "
85	1.235 "	13 081 "
90	1 430 "	15 005 "
95	1.636 "	17.009 "
212	30.000	257·218

Does the above Method apply to all Hygrometers?

It is only applicable to the condensation hygrometer.

How many classes of Hgrometers are in use?

There are two, the Condensation Hygrometer and the Absorption Hygrometer. The former is the only one that is reliable.

Suppose a reading of the dew-point thermometer fall between any two of the numbers in the first column of the table?

In that case take the number in the second column, nearest to the reading, either above or below; the error will be inappreciable. For greater accuracy, see section on Meteorology.

Absolute Weight, Specific Weight, Atomic Weight, Molecular Weight, Molecular Volume.

What Weights are used in Chemistry and Physics?

They are four in number, absolute, specific, atomic and molecular weights.

What is Absolute Weight?

It is the weight of the whole mass of a body without reference to its volume.

What is Specific Weight or Gravity?

It is the weight of a given volume of any substance compared with the weight of an equal volume of some other substance.

What is Atomic weight?

It has already been noticed that atoms differ from each other in quality, quantity and weight. Atomic weight is the relative weight of any atom referred to hydrogen as unity. It is the smallest quantity of any substance by weight, which can enter into combination.

What is Molcular weight?

It is the weight of a simple or compound Molecule, and is formed by taking the sum of the atomic weights of its constituent atoms.

How is absolute weight ascertained?

By the methods of two systems, known as the English and French, or Metrical system of weights and measures.

Why is it important that the student should acquaint himself with the Metrical system?

Because it is already universally adopted by scientists, and promises to become soon the legalized system of all civilized countries.

How is Absolute weight ascertained in Chemistry?

By means of the chemical balance, an instrument of marvelous accuracy, beauty, and usefulness. Loaded with 100 grams, or 1,543 grains, it will still indicate the one-millionth part of the substance weighed.

How is the specific weight or gravity of solids and liquids obtained?

As specific gr. is relative weight, it is convenient to have some fixed standard; for solids and liquids, this standard is pure water at the temperature of 60° F, since the volume of bodies varies with temperature and consequently their density.

What is the practical rule for obtaining it?

Divide the absolute weight of a given volume of the substance, by the weight of an equal bulk of water.

How is the Spe. Gr. of a solid lighter than water obtained?

Divide the weight of the solid by the sum of its weight added to the loss of weight, which it occasions in a heavy body previously weighed in water. Example: A body lighter than water caused the loss of 10 lbs. to a heavier body immersed in water. In air the same body weighed 30 lbs., what was its Spe. Gr.? $30+10=40$, then $30 \div 40=.75$, the answer 40 is equal to its own volume of water.

How is the Spe. Gr. of a body heavier than water obtained?

Weigh it in the water and out of the water and divide as before the weight out of the water by the loss of weight in the water.

How is the Specific Gravity of a Liquid obtained?

The most reliable method is by means of the specific gravity bottle. Balance on the scales a bottle holding 1,000 grs. of water at 60° F.; now

remove the water, and after filling the bottle with the liquid in question, weigh again; divide this last weight by the first and the result will be the specific gravity. Mark the heighth of the water in the neck of the bottle with a file, and it need not be balanced except for the liquid in question.

What is the usual, but less accurate, method of ascertaining Specific Gravity of Liquids?

By means of the Hydrometer.

What is the Hydrometer?

It is an instrument for ascertaining the Specific gravity of Liquids.

What is the principle of the Hydrometer?

It is, that the greater the density or weight of a liquid, the greater will be its buoyancy.

How is the Hydrometer constructed?

There are various hydrometers, but it usually consists of a hollow ball of g'ass, having a graduated stem. A weight is also attached to the ball beneath to steady it in the liquid.

What is a special Hydrometer?

It is one, which is adjusted exclusively to some particular liquid. There are several of these instruments, such as the alcoholometer, lactometer, urinometer, etc. Some are known by the names of their inventors, as Beaume's & Nicholson's hydrometers.

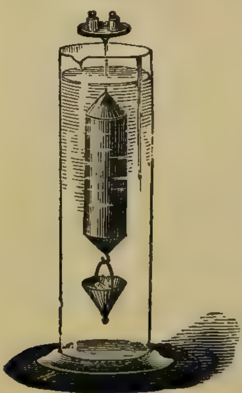


Fig. 4.
Nicholson's Hydrometer.

What is Nicholson's Hydrometer?

It is a hollow cylinder of glass or metal, Fig. 4, weighted at the bottom, and having a small basket suspended at the same point. Above is a stem supporting a plate, on which small bodies and weights may be laid.

How is this Instrument used?

We first ascertain by it the ABSOLUTE weight of the object; then the weight of an equal volume of water, and apply the given rule for obtaining spe. gr.

What is the Process?

The instrument stands vertically in the water; lay the object on the plate, and add weights till the instrument sinks to a marked point on its body or stem. Remove the object, and add again, as much weight as will sink the instrument to the same point. This will be its ABSOLUTE WEIGHT.

Now put the object in the basket below, after removing the weight above. The instrument buoyed by the object in the water, will not sink to its fixed point. Add weight to sink it that far, and this will be the weight of an equal volume of water. Then apply the rule.

How is the Specific Gravity of Gases obtained?

Air is taken as the standard specific gravity for gases and vapors, at the temperature of 32° F., and the barometric pressure of 30 in. for the density of gases, it will be seen, varies both with temperature and atmospheric pressure.

What is the Process?

The same rule applies as for solids and liquids. Weigh the gas, and divide this number by the weight of an equal volume of pure air. A glass

flask is first weighed, absolutely empty. it is then weighed full of air, this gives the standard measure. The gas is now balanced in the same flask, and the number divided by the weight of the air.

What relation does the Metrical System bear to the subject of Specific Gravity?

All the practical applications of its theory are simplified to the utmost degree by the methods of the metrical system of weights and measures. It does this, not only for solids and liquids, but for vapors and gases as well; and for all alike, in the domains of chemistry, physics, manufacture, art and trade.

How is the Specific Gravity of a Liquid determined by the Hydrometer?

For liquids heavier than water, the scale increases from the water, zero, downwards; for liquids lighter than water, it increases from zero upwards. The urinometer is graduated to hundredths of the unit; it is only necessary, therefore to add its indication to 1,000, to obtain the specific gravity.

What is the difference between the Density of a Gas and its Spe. Gr.?

These terms are sometimes used interchangeably; it is proper, however, as has been done in Chemistry, to use the word DENSITY to indicate weight of a given volume of gas, as compared with hydrogen, and the term SPE. GR. to indicate, in like manner, the weight of a given volume of gas referred to air as a standard. The density of oxygen, for example, is 16; its Spe. Gr. is 1. 1087; the density of hydrogen is 1; its Spe. Gr. is 0.0693. Density implies a unit of volume; Spe. Gr. is mere ratio.

Why is it important to ascertain Spe. Gr.?

Spe. Gr. is one of the most important of the physical properties of matter. It is often the means of identifying useful substances without further investigation, and quickly reveals the presence of adulteration in articles of food, medicines, and materials of manufacture and art.

PNEUMATICS.

The Atmosphere, The Barometer, The Air-Pump, Pneumatic Cistern, Diffusion of Gases.

What is Pneumatics?

It is that branch of Physics which treats of the motion, and pressure of gases and vapors.

What is the Atmosphere?

It is the gaseous substance which surrounds the earth, like an ocean, having a depth of more than fifty miles, and which gives life to all organic forms on its surface.

Has the Atmosphere weight?

All gases and vapors, being matter, necessarily possess weight.

What is the most remarkable property of Gases?

All gases and vapors are in the highest degree elastic. The space which a gas occupies depends upon the amount of pressure exerted upon it. There is no known limit to their expansibility as pressure is removed.

What is Boyle's Law?

The volume of a gas is INVERSLY as the pressure.

The density and elastic force are DIRECTLY as the pressure.

The density of a gas is INVERSELY as the volume.

What is the Law of Charles?

Any volume of gas, under a constant pressure, varies DIRECTLY as the absolute temperature.

What is Avogadro's Law?

In the condition of a perfect gas, all substances under like conditions of temperature and pressure, contain, in equal volumes, the same number of molecules.

What importance has this law?

It is the basis of the modern system of chemistry. In the field of the New Chemistry, its discovery is like that of the attraction of gravity to physics, by Sir Isaac Newton.

What is meant by the Reduction of Gases?

It is sometimes necessary to reduce gaseous volumes, both for pressure and temperature under the normal pressure of thirty inches or 760 milimeters.

What is the simple rule of this reduction for Pressure?

Multiply the given volume of gas by the barometric height under which it was measured, and divide the product by 30 or 760 m. m.; the quotient is the true volume.

EXAMPLE—What is the true volume, which 15 cubic inches of hydrogen measured at 29 inches would have, if measured at 30 inches?

By the formula—15x29—30=14.5 cubic inches answer.

What is the Reason of this Rule?

Let H equal the given barometric height.

H' equal any other barometric height.

V equal volume corresponding to first barometric height.

V' equal volume corresponding to second barometric height; then by Boyle's law, since volume is INVERSELY as the pressure, we have the proportion—V: V':: H': H. Hence V' H'=V H or $V'=\frac{VH}{H'}$. This equation is the formula from which the verbal rule has been constructed.

What is the Rule for the reduction of gases for temperature?

By the law of Charles, all gasses, expand or contract by the same amount, for the same increase or decrease of temperature. The amount of this expansion—its coeficient—is $\frac{1}{460}$ of the gas at 32° for every degree F. or $\frac{1}{273}$, if by contigrade, at 0°. $\frac{1}{460}$=. 002174; $\frac{1}{273}$= 003665. The rule, therefore, may be thus stated; for increasing volume, multiply the given volume by unity augumented by the product of .002174 or .003665 by the number of degrees the temperature is raised. For a decreasing volume, divide the given or known volume by unity, increased by the product of the coeficient by the number of degrees the temperature is lowered.

What is the reason of these Rules?

Let V=the known volume.

V'=the unknown volume; and

t°=the number of degrees, the temperature is raised or lowered, then V'=Vx(1+.003665t), for if .003665 is its expansion at 0°, 1+003665 will be the expansion at 1° by the law, and 1+.003665+2 at 2° and 1+003665x3 at 3° and 1+(003665xt) volumes at t°.

So that the above equation is the formula for the first rule, and the second is easily deduced from it by transposition of terms: $V=\frac{V'}{(1+.003665t)}$, the formula of the second.

EXAMPLE—A gas measures .9154 cubic inches at 9° what will it measure at 60° ?

$V' = .9154 x (1 + .003665 x 60) = 1.1167$ cubic inches.

A gas measures at 100° 40.1 c. c., what will it measure at 0° ?

$V' = \frac{40.1}{(1 + .003665 x 100)} = 29.345$ c. c.—answer.

What is the amount of pressure of the Atmosphere for each square inch of surface at the sea level ?

It is 14.6 lbs. or nearly 15 lbs, and this is called an atmosphere; 30 lbs. would be 2 atmospheres, etc.

Was the Weight of the atmosphere known to the Ancients ?

This fact has been known only since the days of Torricelli, about 200 years.

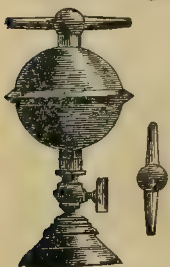


Fig. 3—Magdeburg Spheres.

What is a Vacuum ?

It is a portion of space where no matter is. There is no perfect vacuum.

When the air is removed from a tube or jar in water, why does the water instantly fill it ?

Because the air being removed, a vucuum is formed, and the pressure of the Atmosphere upon the surface of the liquid external to the tube, forces it up to occupy the place of the air, there being no longer any elasticity of the air above to resist it.

What are the Magdeburg Hemispheres ?

In 1654, Otto Guerike made the first exhibition of the powers of the air pump, by a pair of Magdeburg Hemispheres. These consist of two hollow cups of brass fitting air tight, which being united, are screwed to the plate of the air pump, the air exhausted in their interior, and the vacuum secured by means of a stopcock. The cups cannot, now, be separated without a great force antagonizing the pressure of the external air. Fig. No. 3.

What is the Syphon?

It is a tube bent like the letter U, so as to have one leg or side longer than the other, to contain a longer column of water or other fluid.

What is the principle of its action?

The longer column having the greater hydrostatic pressure, the fluid must run in that direction, while the upward pressure in the shorter leg will sustain the flow so long as its open end remains below the surface of the fluid.

Describe the Cup of Tantalus.

Fig. 6.—Cup of Tantalus

This curious toy consists of a cup or tumbler, with a syphon concealed within. The water being poured in, will, of course, rise in the shorter leg, which opens in the cup, and, as soon as it rises above the bend, it must begin to escape by the longer leg, which opens outside through the bottom. Fig. 6.

Who discovered this Principle?

Torricilli, 1642, the famous pupil of Galileo.

How did this discovery lead to the invention of the Barometer?

Torricelli, (TORRICHELLI) had used a glass

tube more than thirty inches in length, which he filled with mercury, one end being open, so as to compare its height with that of water in the common suction pump. This column of mercury was observed to fluctuate, from day to day, within a certain space, and, therefore, to indicate variations in the weight of the incumbent atmosphere. The addition of a simple scale of inches or milimeters, to a mounted tube to mark these fluctuations gave origin to the barometer.

Is the cause of these variations in the weight of the atmosphere well understood?

Several theories have been advanced to account for them, but none is wholly satisfactory.

What are the different forms of the Barometer?

There are various forms of this useful instrument, but the principle is the same in all. Those most in use are the cistern and siphon barometers. The wheel barometer is a mere toy, and the aneroid, though elegant and ingenious, is liable to get out of repair.

What is the construction of the Cistern Barometer?

It is merely the inverted tube of Torricelli, thirty-four inches in length, and rests at one end in a cistern of mercury, to which the air has free access. The siphon barometer is the same tube bent in the form of the siphon. It is inferior to the first instrument.

On what does the value of the Barometer depend as a scientific instrument?

It depends on the purity of the mercury and the total exclusion of atmospheric air. For this reason, the most carefully constructed instruments are liable to gradually deteriorate.

How may a Cistern Barometer be easily tested?

Carefully invert the tube, and let the mercury fall with some force upon the closed extremity. In a perfect instrument the stroke will give a ringing metalic sound, but if air or other impurities be present the sound will be dull.

What are the uses of the Barometer?

It is valuable in Astronomy to determine the amount of atmospheric refraction; it indicates climate by determining attitude; it measures the height of mountains and table lands; it is indipensible, as already seen, in certain important reductions of gases and vapors, and in connection with the vast telegraphic systems of the age, it has become invaluable as an indicator of approaching storms and changing weather.

How has the Telegraph enhanced the value of the Barometer as a weather indicator?

The chief points to be attended to, in observations by the barometer, are its fluctuations taken in connection with the wind and the state of the sky, but, above all, its readings AS COMPAIRED WITH THOSE AT NEIGHBORING OR DISTANT PLACES, SINCE IT IS DIFFERENCE OF PRESSURE, WHICH DETERMINES THE STRENGTH OF THE WIND AND THE WEATHER GENERALLY.

What corrections are required for nicely accurate barometric readings?

There are three possibly; the corrections for Capillarity, for Temperature and for Capacity.

What is the Reason of the correction for Capillarity?

The effect of the attraction of the walls of a glass tube upon mercury, is what is called

REVERSED capillarity. That is, the metal, instead of rising like water in the bore, is considerably DEPRESSED, so that the apparent reading is not the true height of the column. It is too low, a fraction must be added, and this quantity varies inversely as the diameter of the tube.

If the diameter equals .6 of an inch no correction for capillarity is required.

The following table gives the corrections for different diameters:

Diam. of Tube inches.	Depression inches.	Diam. of Tube inches.	Depression inches.
.10	.1403	.40	.0153
.15	.0863	.45	.0112
.20	.0581	.50	.0083
.25	.0407		
.30	.0292		
.35	.0211		

What is the Rule for correction for Temperature ?

Subtract the .0001 part of the observed height of the mercury for every degree of Fahrenheit above 32°.

EXAMPLE—Suppose the Thermometer—which is appended to every approved barometer—indicates 60°, while the barometer stands at 30 inches, the correction will be (60—32x30x.0001=.084 This number being substracted from the observed height, reduces it to the corresponding heat at 32°, this being the unit of heat for expansion of the mercury.

What is the reason of this Rule ?

The column of mercury in the barometer is affected by variations of temperature precisely as that in the tube of the thermometer, and thus the accuracy of its readings is viciated, more or less, for every degree of temperature above the freezing point of water.

Correction for temperature, therefore, consists in first finding, and then removing the temper-

ature expansion of the column from its elevations due, alone to atmospheric pressure.

Let x=the correction sought;

Let b=height of mercury in barometer:

Let a=height above freezing point of mercury in thermometer;

32°=unit of heat for mercury expansion, .0001 being the increment of expansion for every degree above 32°F., then we have x=b—(a—32)bx.0001, the formula for the rule. The increment of expansion of mercury from 32° to 212° by Fahrenheit's scale is $\frac{1}{9742}$=.0001 nearly; and by centigrade it is $\frac{1}{5412}$, also, equal nearly to .0001. As in the use of the hygrometer, all this is simplified and made easy in practice, by a convenient table of corrections for each degree of the scale from 32° to 100°, and for every half inch of the barometric scale from 27.5 to 30.5 inches. The student can construct one for his own use from the formula. The following are corrections for two degrees of the thermometer for each half inch of barometer:

Barometer Scale. inches.	Temperature.	Corrections. inches.
28		.0028
28.5		.00285
29	33°	.0029
29.5		.00295
30		.00030
30.5		.00305
28		.0056
28.5		.00570
29	34°	.0058
29.5		.00295
30		.0060
30.5		.00610
28	54°	.0616
28.5		.06270
28	100°	.1904

What is Correction for Capacity?

This is simply an adjustment by which the zero point of the scale it made to correspond with the level of the mercury in the cistern. This is done either by causing the scale to move towards the cistern or the cistern to the scale. The latter is the usual adjustment in good instruments.

What is the Reason of this Correction?

As the mercury rises or falls in the tube, there is, of course, less or more of the fluid in the cistern. Its surface level no longer corresponds with the zero of the scale, and consequently the readings of the instrument do not give its true indications. This correction is provided for by means of adjusting screws in all perfect cistern barometers.

What is the Pneumatic Trough or Cistern?

It is a vessel of glass or metal, usually designed to collect and preserve gases. Having the form of a tank, it is filled with water or mercury, and supplied with perforated shelves on which glass jars, inverted and filled with water or mercury, stand ready to receive the gases, delivered through the perforations over which they rest. See Fig. 19.

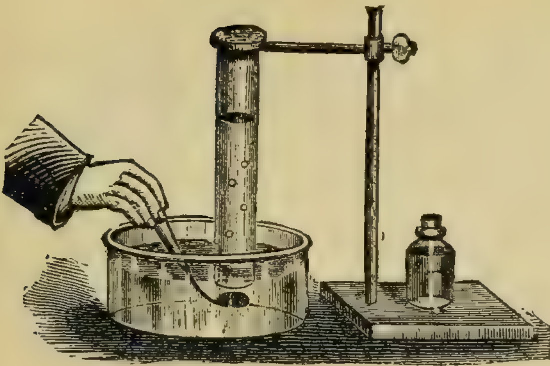


Fig. 19—Pneumatic Cistern.

What causes the fluid to be supported above its level in the jars after their inversion?

Because, as already explained, the pressure of the atmosphere on the surface of the water or mercury in the cistern sustains the column of it in the jar.

Why do gases pass from a delivery tube into the jar, thus inverted, and gradually displace all the liquid suspended in it?

Gases are lighter than water, and must, when free to move in it, rise to the surface. But gas and water can not occupy the same space at the same time, on the principle of the irrisistibility of matter; that is, no two bodies can occupy the same portion of space at the same moment. Therefore, the liquid flows out and gives its place to the gas.

What is the Air Pump?

It is a machine for exhausting the air from any vessel suited to the purpose. See Fig. 1.

What is the Principle of its construction?

It is constructed on the principle of the elasticity of the air.

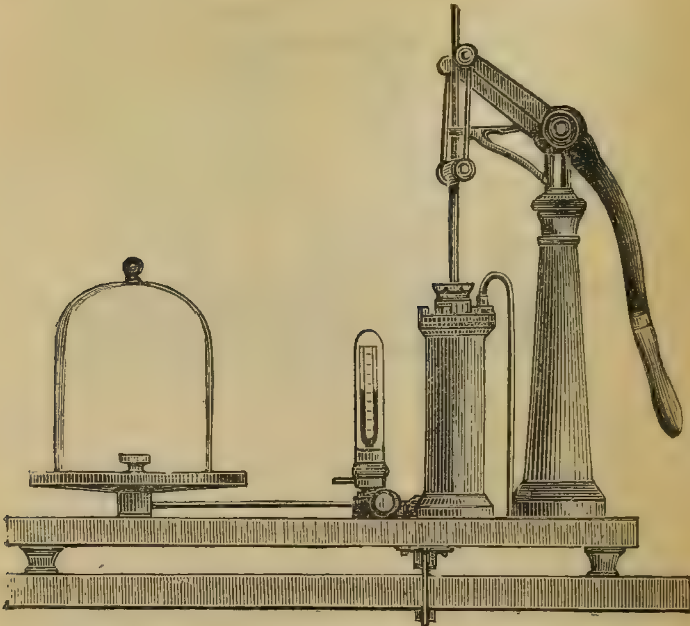


Fig. 1—Air Pump.

What is meant by its Elasticity ?

Its elasticity is its constant tendency to expand as pressure is removed.

Is the air like other gases Elastic ?

Like them, it is perfectly elastic, and as the pressure is removed indefinitely, it continues to expand indefinitely ; so that there has not been found a practical limit to its power of expansion.

What is the reason for this indefinite expansibility ?

It is accounted for by the principle of self-repulsion, which seems to be inherent in the molecules of all gaseous matter.

What is the construction of the Air Pump?

The air pump is simply an exhausting syringe, whose piston is moved by a powerful lever, rendering it more efficient in pumping the air from the receiver placed upon the plate of the machine. A description of the exhausting syringe will, therefore, give the construction of the air pump.

What is the Exhausting Syringe?

Fig. _. Exhausting Syringe.

It consists of a hollow cylinder, to which is fitted an air tight piston. The cylinder communicates by a screw and pipe at the bottom with a vessel, generally a receiver, from which the air is to be withdrawn. The piston carries a valve which opens upward, and connected with the pipe at the bottom, is another valve, also, opening upward. If, now, the piston be raised, a vacuum being formed in the cylinder, the air in the receiver expands, and instantly rushes into the cylinder, and passes out through the valve in the piston, as it descends against the bottom of the cylinder. It is obvious that a few strokes of the piston will so expand, the air in the receiver as to produce there a virtual vacuum.

The simple syringe arranged either singly or in pairs, and so adjusted as to be worked with a strong lever, having its cylinder in connection with a perforated, metalic plate, on which a receiver may be placed, or to which any piece of apparatus may be screwed, constitutes the air pump.

What are the uses of the Air Pump?

It demonstrates the existence of weight in the atmosphere, and serves several useful purposes in the laboratory and the arts.

What is the numerical statement of the pressure of the Atmosphere?

It is generally stated to be fifteen pounds upon every square inch of surface; 14.6 pounds would be nearer the truer pressure. This is called one atmosphere; thirty pounds would be two atmospheres, etc.

What is the Cupping Apparatus or Glass?

It is a minature air pump. The principle of its action is illustrated by the hand glass on the plate of the air pump; the air being exhausted over a portion of the skin, the outside pressure of the air causes it to swell out and protrude into the glass.

What is Gaseous Diffusion?

It is the remarkable property possessed by gases and vapors of passing into and mixing with each other, even against the law of gravity.

What is the Law of Gaseous Diffusion?

The diffusive power of a gas varies inversely as the square root of its density. Example—hydrogen and oxogen as to their densities, are to each other as 1 to 16; their relative rates of diffusion are as 4 to 1, the square roots, respectively, of 16 and 1.

Does not this Law admirably illustrate the wisdom of God?

If no such law reigned in the world of vapors and gases, they would necessarily be associated, like oil and water, in the order of their specific gravities, so altering the condition of our atmosphere as to make animal life on the earth

impossible. "It is impossible to over-estimate the importance in the economy of Nature, of this very curious law affecting the constitution of gaseous bodies; it is the principal means by which the atmosphere is preserved in a uniform state, and the accummulation of poisonous gases and exhalations in towns and other confined localities prevented."

What important distinction is here necessary?

The real diffusion of gases, must not be confounded with another property they possess, of being transmitted through membranous diaphragms, such as bladder, India rubber and gold-beater's skin. This is osmose, when dissimilar gases mix through porous diaphragms.

What is Osmose?

It is the power possessed by gases of intermixing readily through partitions of membranous substances.

What are the essential differences between Diffusion and Osmose?

Osmose, although partly due to the principle of diffusion, necessitates the presence of membranous diaphragm; diffusion, on the contrary, takes place under all conditions in which gases are free to mix with each other. Diffusion purifies the air before it enters the lungs; osmose corrupts it there with the poison from which diffusion had healthfully cleansed it.

How is the Diffusion of Gases accounted for?

Diffusion takes place, whenever, the cohesive force of molecules is exceeded by the adhesive force which attaches them to the molecules of some other body. But gases have no cohesive force among their molecules, hence they readily intermix uniformly and in all proportions.

How is Osmose of Gases accounted for?

Osmose is partly due to the law of diffusion, even, through minute pores, but the force of adhesion, as exerted by the membranous partitions upon the gaseous molecules, plays an important part in the process. The stronger this adhesion between the membrane and the molecules, the more rapid and abundant will be the osmose of the gases. They are condensed and liquified by the power of the adhesive force, and passing thus through the wet membranes, evaporate and re-appear on the other side as gases again.

What is Absorption of Gases?

The diffusion of gases through liquids. This varies greatly for different liquids and gases, and for the same liquid and gas under different temperatures. Cold and pressure increase it; heat, on the contrary, lessens it.

Are there now any Permanent Gases?

All the gases, even the most refractory, such as hydrogen and oxygen, have, at last, by a new and recent process, been liquified. This event constitutes a new era in Physics, and must lead to great results.

CRYSTALLIZATION.

Amorphism—Isomorphism—Sublimation.

What is Crystallization?

When certain bodies pass from the liquid or gaseous to that of the solid state, their molecules have the power to arrange themselves in regular geometrical forms. This is crystallezation, and the forms themselves are called crystals.

What is Amorphism?

Many substances do not possess this power to crystallize as they pass into the solid state; they are, therefore, amorphous, that is, without form, as glass.

Under what conditions may Crystals be produced?

From melted substances slowly cooling—from solutions as sugar—from the condensation of gases as in the production of nitric acid, and from the re-arrangement of the molecules of a solid, as the slow crystallization of railroad axles by constant agitation.

How are Crystaline Bodies distinguished from each other?

It is a general law that all crystalline substances have their peculiar forms, and this peculiarity of form is dependent upon certain characteristics which are easily discovered in each.

To what classification does this give rise?

It divides all crystalline bodies into six systems.

What are the Systems of Crystallization?

First—The MONOMETRIC or CUBIC system.

Second—The DIMETRIC or PYRAMIDAL system.

Third—The RHOMBOHEDRAL system.

Fourth—The TRIMETRIC or RIGHT PRISMATIC system.

Fifth—The MONOCLINIC or OBLIQUE PRISMATIC system.

Sixth—The triclinic or double oblique prismatic system.

What are the characteristics of these systems?

In every crystal certain straight lines may be imagined to be drawn through its centre from side to side, from end to end, or from angle to angle, around which it has grouped its molecules to produce its own peculiar form. These lines are called AXES and are its characteristic mark.

What is the characteristic of the first system?

Three equal axes; all at right angles to each other.

Of the Second?

Three axes at right angles, but one unequal—either longer or shorter than the other two.

Of the Third?

Three axes, two of them equal, and at an angle of 60°; the third and principal one being at right angles to the other two. This is one of the most interesting and extensive of all the systems.

Of the Fourth.

Three axes, all unequal and at right angles to each other.

Of the Fifth?

Three axes, which may be all unequal; two of them at right angles to each other, while the

third is oblique to one and perpendicular to the other of the first two axes.

Of the Sixth?

Three axes, all of which may be unequal in length, and all oblique to each other. This is the form to which belong copper sulphate, bismuth nitrate, and potassa quadroxalate.

What is Isomorphism?*

Any two or more substances, which have the same form of crystallization, are said to be isomorphous. These bodies are generally similar in chemical constitution. They will replace each other in crystallized compounds without alteration of the crystalline figure.

What is Dimorphism? †

Under different circumstances of high or low temperature, the same substance may assume different crystalline formes. This is dimorphism. Carbon and sulphur are notable examples.

What are the Isomorphous Groupes of elements?

There are eight:

First—Sulphur, Selenium.

Second—Magnesium, Calcium, Manganese, Iron, Cobalt, Nickel, Zinc, Cadmium, Copper, Chromium, Aluminum.

Third—Barium, Strontium, Lead.

Fourth—Platinum, Iridium, Osmium.

Fifth—Tin, Molybdenum.

Sixth—Sodium, Silver, Gold, Potassium, and perhaps Ammonium.

Seventh—Chlorine, Iodine, Bromine, Fluorine.

Eighth—Phosphorus, Arsenic, Antimony Bismuth.

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*From isos equal and morphe form, of the Greek.
†From dis two times and morphe form.

It will be seen in another place, that these isomorphous elements are often likewise similar in their combining capacity—that is, in quantivalence.

Is there not a more general c'assification of all crystalline forms?

They are divided into PRIMARY AND SECONDARY OR DERIVED forms.

What is Primary Crystal?

It is one, which has been developed by equal additions on every part of it in accordance with the regular law.

What is a Secondary or Derived Crystal?

It is one whose development has been by unequal additions to the several parts of it, yet these additions being deposited in obedience to the usual geometric law of arrangement. A form different from the primary is thus produced but obviously related to it.

What striking Phenomena accompany Crystallization?

Increase of volume is a notable result; 1,000 parts of freezing water expand to 1063 parts in crystals of ice. This force of expansion is so great as to shatter the strongest walls of iron. Heat is a constant result of crystallization, and occasionally flashes of light.

What is the Goneometer?

The goneometer is an instrument for measuring the angles of crystals, in order to ascertain the system to which each may belong.

What is Sublimation?

It is a solid passing into a gaseous condition and the reverse.

MAGNETISM.

Electro-Physics, Electro-Physeology, Electro-Diagnosis, Electro-Therapeutics, Electro-Medicine, Electro-Surgery, Electro-Therapeutical Apparatus, Special Applications of Electricity.

What is Magnetism?

It is that branch of Physics which treats of the phenomena of magnets, both natural and artificial.

Is anything known of the Nature of this force?

Nothing; it is a form of electricity.

What is the Natural Magnet?

It is the black oxide or magnetic iron ore, crystalized in cubes, and one of the most valuable of iron ores. A fragment of this oxide, if properly suspended, will turn one side to the North, and the opposite to the South. It, therefore, manifests polarity.

What is Polarity?

Polarity is a general term, and in this sense means simply two opposite states or conditions, whatever they may be. Hence there is magnetic polarity, electric polarity, polarity of light, and the polarity of chemical affinity. It is an essential principle in all Physics.

What is an Artificial Magnet?

Bars of iron and steel can be made magnetic by simple contact with a natural magnet; and then again, may impart their polarity to other pieces of the same metal.

What is the Attractive Force of a Magnet termed?

The attractive force of a magnet is called its **Magnetic Force.**

What are the Poles of a Magnet?

They are the two opposite points, where its magnetic force is most strongly exerted.

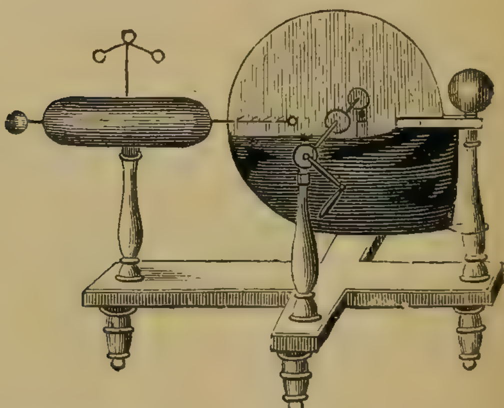
What is the general Law of Polarity?

Like poles repel each other; unlike poles attract each other.

What is Magnetic Induction?

It is the power which any magnet possesses of imparting its magnetic force to other bodies in contact with it or in its neighborhood. Soft iron loses its induced magnetism on the removal of the inducing magnet, but steel retains it permanently.

ELECTRICITY.



What is Electricity?

It is a subtle agent of whose nature, we yet

know nothing. Like heat and magnetism it is a mode of motion of the molecules.

How is Electricity excited?

If a rod of glass, or piece of sealing wax be rubbed with a warm silk handkerchief, a crackling noise will be heard, and if it be dark. sparks will appear. This is frictional or Franklinic electricity.

What are Electrics?

Any substances that manifest electrical excitement by friction, such as the glass rods and sealing wax above, are termed ELECTRICS.

What are Conductors and Non-conductors of Electricity?

Some substances give ready passage to electricity; those are called CONDUCTORS; there are other bodies that retard or almost prevent its passage; these are NON-CONDUCTORS. The last are also called INSULATORS.

What are the best Conductors of Electricity?

The metals, charcoal, the earth, all liquids. except oil, moist air, water and the human body.

What are the best Insulators?

Gum shellac, gutta percha, sulphur, sealing wax, glass, all resinous bodies, silks, feathers, hair, dry air, dry wool and baked wood.

In how many forms does Electricity appear to manifest itself?

In two forms—VITRIOUS and RESINOUS electricity. Franklin named them positive and negative electricity, distinguishing them by the signs (+) and (—) plus and minus.

What is the general Law of Electricity?

Like electricities repel each other; unlike

attract each other. This is the polarity of electricity.

What is Electrical Tension?

The degree of electrical excitement in any body is its ELECTRICAL TENSION. I s release is called DISCHARGE.

What is Electrical Induction?

It is the power which an electrically charged body possesses of distributing the electrical condition of other bodies at a distance from itself. It is partial conduction, or a preparation for passage from one body into another. The molecules in all substances are more or less susceptible of electrical excitement.

What is the Velocity of Electricity in Motion?

Some have estimated its velocity of motion as high as 280,000 miles per second; but practically the United States Coast Survey found it to pass through iron wire with a velocity of only 20,000 miles per second.

How is Frictional Electricity obtained?

Usually from an apparatus called the ELECTRICAL MACHINE. It may now, however, be obtained in far greater abundance and convenience from a Ruhmkorff's coil, an electro-magnetic apparatus yet to be described.

What is a Leyden Jar?

It is a glass vessel having a wide mouth, more than one half of whose internal and external surface is lined with tin foil. The mouth is closed with a cover of baked wood, through the middle of which passes a metalic rod, the upper end terminating in a ball, and the lower in a chain hanging down in contact with the foil on the bottom of the jar.

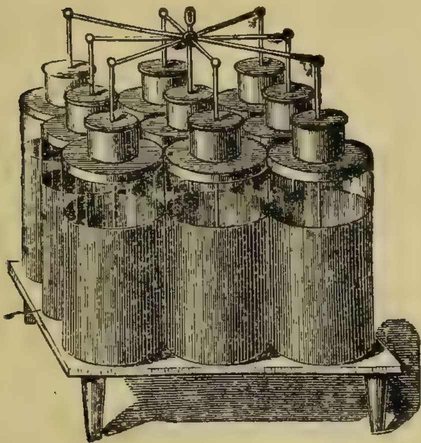


Fig. 14.—New Electrical Battery.

What is the Electrical Battery?

It is a combination of Leyden Jars, so arranged that they may be all at the same time charged from the electrical machine, and all at the same moment discharged.

What does Figure 14 represent?

It illustrates an improved battery of Leyden Jars.

Is Franklinic or Frictional Electricity of any Therapeutical importance?

This form of electricity is no longer used medicinally, having been superseded by the more convenient and efficient applications of galvanic and faradic electricity.

What is Galvanism or Galvanic Electricity?

It is the electricity produced by the chemical action of two or more dissimilar substances upon each other. The same form of electricity is sometimes called Voltaic electricity.

What simple Experiment illustrates the production of Voltaic Electricity?

Place a silver coin on the tongue, and a piece of zinc underneath it; when the metals are made to touch each other, the tongue will experience a peculiar thrill, the mouth a metalic taste, and the eyes, if closed, a sensation of light.

How does Galvanic Electricity differ from Franklinic Electricity?

Franklinic electricity is intense in action, and quick to seek equilibrium by discharge; it does not flow in a steady stream, but leaps to its object like a river over a precipice. Galvanic electricity, on the contrary, with little intensity flows quickly in a constant, unbroken current.

Is not this distinction very important?

It is; for it is the sole explanation of the superior practical utility of Galvanic electricity in Medical Surgery and Arts.

What Principle forms the basis of the Science of Galvanic Electricity?

Two solid, conducting bodies, usually metals, being immersed in a compound liquid, which acts unequally upon one of them, disturbs electrical equilibrium. One of the metals becomes positively excited and the other negatively; this is the polarity of Galvanism and the basic principle of the science.

Which is the Electro-positive metal or body, and which the Electro-negative?

The metal most easily acted upon, is termed the electro-positive metal, and the other the electro-negative.

What is the Power thus generated, called?

The ELECTRO-MOTIVE FORCE.

What is the classification of bodies, which are capable of producing the Electro-motive Force?

All the elementary substances may be so arranged in a series, that any one above in the series, shall be negative to any that is below, and any one that is below shall be positive to any above. The more remote they stand from each other, the more powerfully will their contact be productive of electricity.

What substances are most in use for this purpose, and what is their relative arrangement?

Carbon, Antimony, Gold, Platinum, Silver, Copper, Tin, Lead, Iron and Zinc.

Zinc and charcoal are, therefore, the most powerful generators of electricity in such a combination, and copper and tin among the least.

What are the Essential elements of a Galvanic Combination?

There must be present, at least, three elements, one a solid, the second a fluid, and the third either a solid or a fluid.

What is a Galvanic Circuit?

When the elements are so arranged that there is a continuous flow of positive electricity in one direction, and of negative electricity in the opposite, a galvanic circuit is formed.

Where will be the strongest manifestation of Electrical Action?

At the point where the two currents meet—where the poles of the combination are nearly in contact.

What names are given to these Poles?

The free end of the wire attached to the zinc plate is called the NEGATIVE ELECTRODE, the

extremity of that attached to the copper or carbon plate, the POSITIVE ELECTRODE. It must be remembered, however, that the zinc plate is positive, and the copper or carbon negative.

When is a Galvanic Circuit said to be closed?

When the electrodes are in contact, the circuit is said to be closed. The current still flows, however, but gives no sign.

What distinct names are sometimes given to the Poles of a Galvanic combination?

The positive pole is sometimes called the ANODE, and the negative the cathode, from two Greek words, ana upwards and oidos a way, kata downwards and oidos. The first belongs to the positive wire and the second to the negative.

The term pole, so often applied above, must not mislead the student into the idea, that attraction and repulsion are properties of the electrodes in the galvanic cirtuit. Faraday proved the contrary.

Do both plates or metals of a circuit, serve to generate Electricity?

One—the positive—acts on the generator, the other—the negative—as a conductor of electricity. The zinc plate is the positive generator; the copper or carbon the negative conductor.

What is a Galvanic Cell?

A single combination of the essential elements of a circuit.

How may the quantity of galvanic Electricity be increased?

By enlarging the plates of a cell.

How may the Tension or Intensity of galvanic action be increased?

By multiplying the number of the cells. This constitutes a compound battery.

What are the principle Galvanic Batteries now in use?

Smee's, Daniel's, Grove's and Bunsen's, and the Cromic Acid Battery.

What is Smee's Battery?

It is the simplest in use. Its combination is two metals and one liquid, the metals being zinc and silver, and the liquid a weak solution of sulphuric acid and water. The silver plate is coated with platinum, and the zinc with mercury.

What is Daniel's Battery?

It is the battery of best sustained action. The combination is two metals and two liquids; copper and zinc, diluted sulphuric acid, and a saturated solution of copper sulphate.

What is Grove's Battery?

This is the battery of greatest galvanic action. Its combination is two metals and two liquids, zinc and platinum, weak sulphuric acid and strong nitric acid.

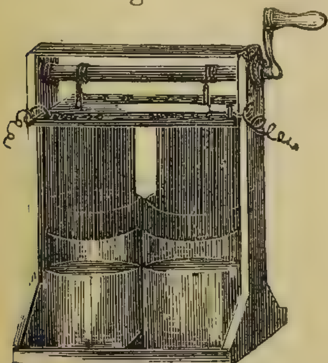


Fig. 17.—Bunsen's Battery.

Fig. 17 represents an efficient Bunsen's Battery composed of two cells, large glass jars, each containing five carbon and five zinc elements, with windless and crank for raising and lowering. All of the apparatus described in these pages, are made in the highest perfection by Hall & Benjamin, of New York.

What is Bunsen's Battery?

Bunsen's is a modification of Grove's, making

it cheaper, but a little less powerful, by substituting carbon plates for the more expensive platinum.

What is the Chromic Acid Battery ?

This is a modification of Bunsen's battery. The zinc is amalgamated, and the jār filled with a saturated solution of salt or sulphuric acid diluted with twenty parts of water. The porous cup is filled with a solution made by dissolving one pound of potassic bicromate in ten pounds of hot water, and when cold adding five pounds of strong sulphuric acid. This is a convenient and inexpensive battery and much used.

APPLIED ELECTRICITY.

Faradaism, Faradic Electricity, or Electro-Magnetism and Magneto-Electricity.

What is Faradic Electricity or Faradaism ?

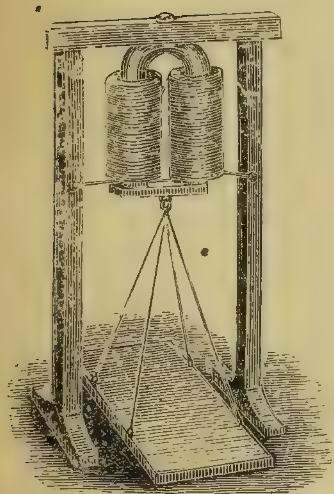
This is identical with electro-magnetism, which is that form of magnetism that is produced by the action of the electric current. This was discovered by Faraday, in 1831.

What was the extent of Faraday's Discovery ?

He discovered, as Franklin had done in the case of atmospheric and common electricity, the identity of common electricity with galvanism, magnetism and thermo and animal electricity.

What was the extent of Œrsted's Discovery ?

Œrsted's discovery was limited to the effects of the electric current on needles, that were already magnetized. He first revealed the powers of the UNINTERRUPTED CURRENT.



What is Electro-Magnetism?

It is magnetism developed through the agency of electrical action.

Fig. 20.—Electro-Magnet, sustaining 150 lbs.

Is not this uninterrupted current the great distinction between Electricity and Electro-Magnetism?

Franklinic electricity is capable of a quiet current; and galanic electricity, previous to the time of Œrsted, was limited to the action of a broken current between the electrodes; but electro-magnetism is such, only in virtue of its uninterrupted currents.

What are Induced Currents?

They are currents which are produced by the action of magnets or other electro currents. They constitute electro-magnetism.

What is the Mode of their Production?

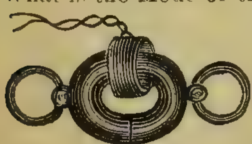


Fig. 16—The Magic Circle.

When two conductors, as iron wires, are arranged parallel, and near each other, each induces an opposite current in the other. If the circuit be broken again, another current

passes in the same direction as the first or primary current, inducing another secondary current; so that at each close and break of the circuit, rapidly made, the electrical intensity is powerfully increased. A current of electricity passing through ONE TURN in a coil of wire, induces two secondary currents in all the other TURNS of the coil. The effect of the latter must, therefore, be added to the primary. This was Faraday's discovery, and hence induced electricity is called Faradaism.

What is shown by the Magic Circle?

An electric current being sent around the coil the united pieces of soft iron become powerfully magnetized, and are held together with great force, as long as the current continues.

What is an Induction Coil?

If several hundred feet of stout copper wire be wound closely around a hollow cylinder, and another finer wire of several thousand feet, both carefully insulated with silk wrappings, be wound upon the first wire in a secondary coil, a current sent through the first, and rapidly interrupted, will induce secondary currents in the other wire of such intensity, as to manifest all the phenomena, such as sparks and shocks of a powerful electrical machine.

Can the Magnet induce these primary and secondary currents as well as Electricity?

It can, and a powerful steel magnet is capable of intensifying the currents to such a degree, by secondary currents, as to exhibit all the phenomena described above.

What is the mode of its action?

Let the keeper or armature of a powerful steel

magnet, be wrapped with a very long insulated coil, and then be so adjusted as to revolve by multiplying wheels with great velocity in front of the poles of the magnet. This reverses with equal rapidity, at each half revolution the induced polarity of the keeper, giving rise, in the coil, to powerful magneto-electric currents. This is magneto-electricity, and another source of Faradaism. The apparatus is called the Magneto-electric Battery.

Is it not highly probably that this whole phenomenon of Dynamic Induction, is only an altered direction of the electric current, producing what is called Magnetism?

This is Ampere's theory; and it is remarkable that the electric current, contrary to the action of all the other physical forces, induces a motion always at right angles to its own line of direction. This altered direction of motion is magnetism, and the only difference between electricity and magnetism.

How may Faradaism, therefore, be again briefly defined?

It is the magnetization of the coils or helices,* inducing thereby all the phenomena of electricity.

Will not the same magnetization take place in an iron rod or a bundle of such rods—permanently if steel, and temporarily if soft iron—placed in the hollow of a helix in connection with an electro-battery?

Such rods will be intensely magnetic so long as the connection is maintained, but cease to be so as soon as the connection is broken. This principle or adjustment is very important in the construction and action of electrical apparatus.

What is Neef's Induction Coil?

*The word helix is Greek, meaning a cork screw.

Dr. Neef's coil is a happy combination of Electro-magnetism and Magneto-electricity. Insert into the hollow cylinder of the induction coil a bundle of soft iron rods, and upon their upper extremity, adjust a plate of soft iron, which can be alternately attracted to and freed from the rods as the interrupted currents pass through the coils, thus producing a rapid automatic closure and breakage of their currents. This is Neef's coil, an invention, which so improved the apparatus of Electro-therapeutics as to raise it at once to the dignity of a special science.

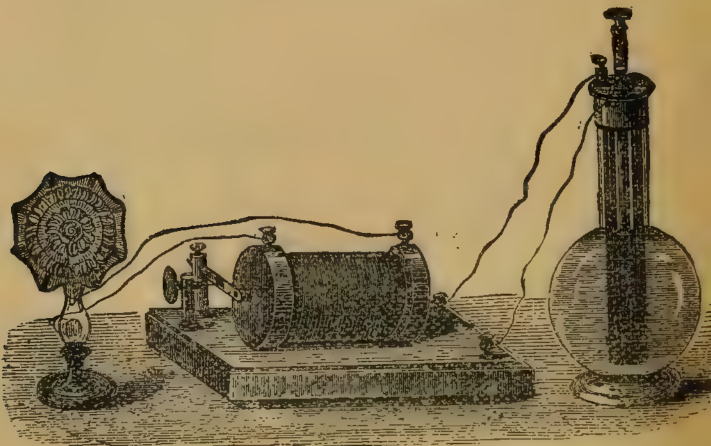


Fig. 13.—Ruhmcorff's Coil.

What is Ruhmcorff's Coil?

This apparatus, is nothing more than Neef's, with an improved insulating material or fixture for the coils. It is capable of yielding long electric sparks, and most deadly discharges of electricity.

What is the Galvenometer?

It is an instrument for measuring the intensity of electric currents. The principle of it is, as already stated, that a current of electricity will deflect a magnetic needle at right angles to the current.

What was the extent of Sir Humphreys Davy's Discovery in Electro-Physics?

He established the fact that the electro-current will induce magnetism in pieces of iron and steel not previously magnetized.

What was Dr. Henry's Discovery?

He discovered the method of constructing efficient electro-magnets. This invention made way for the telegraph.

ELECTRO-PHYSIOLOGY.

What is Electro-Physiology?

It is that branch of Electro-Physics which considers the vital relations of electricity in all its forms, to the functions of the living animal. It includes, also, in a special sense, what is known as ancient electricity.

Under what particular heads may the student of Electro-therapeutics study this subject?

First—Its general effects upon the nerves and muscles.

Second—Its action on the brain and spinal cord.

Third—Its action on the nerves of special sense.

Fourth—Its action on the muscles, both voluntary and involuntary.

Fifth—Its tonic and neutritive effects upon the system.

Sixth—What are the different effects on these several heads of Faradic Electricity.

ELECTRO-DIAGNOSIS.

What is Electro-Diagnosis?

It is the application of galvanic, and faradic electricity to the detection of special diseased conditions. This art is rapidly growing in importance, with the increasing use of electricity in Medicine.

Upon what does its successful application depend?

It depends upon the exercise of much acute observation, careful manipulation, and more especially upon the important faet, that the effects of electricity are sensibly modified by the presence of disease in any organ.

What names are given to these Diagnostic signs?

They are called QUANTITATIVE and QUALITATIVE REACTIONS of Electro-therapeutics. The first is sometimes termed the reaction of degeneration, and consists in an alteration in the order of occurrence of the contractions.

METHODS OF APPLICATION.

What is embraced in the term Electrization?

It includes every form and detail of the therapeutical applications of electricity.

How many and what are the chief methods of Electrization?

There are four of these methods:
First—Localized Faradization.
Second—Localized Galvanization.
Third—General Faradization.
Fourth—Central Galvanization.

What is Local Faradization?

It is the art of limiting the effects of the faradic current to certain organs and tissues.

What is Local Galvanization?

It appears to be the art of so applying galvanic electricity, as to produce certain effects, and no others in any special organ or tissue. In other words, it is the art of making the current act at will, as a sedative, stimulant or tonic, etc.

What is General Faradization?

It is such an application of faradic electricity as will bring all the internal organs and tissues, and the entire surface of the body under the influence of the induction current. For general electrization the faradic current is always preferred; galvanization is too potent in its effects.

What is Central Galvanization?

It is that method of treatment by which the whole central nervous system—brain, sympathetic nerves and spinal cord—are brought under the influence of the galvanic current.

This application requires a familiar knowledge of Electro-physics, with a deep insight into both the functional and structural derangements of the nervous system.

ELECTRO-SURGERY.

What is Electro-Surgery?

Electro-surgery is that branch of Electro-therapeutics, which treats of electrolysis, and the processes and methods of galvano-cautery.

What is Electrolysis?

In a wider sense, according to the etymology of the word, *electron* and *luo* to set free by electricity, electrolysis means the decomposition of any compound substance by electricity. In surgery it signifies the same application of electricity to any diseased tissue or structure of the living organism—such as tumors, moles and nævi.

To what altered structures has the Electrolytic process been applied with more or less success?

It has been used in erectile and cystic tumors with remarkable success, in goitres, fibroids, cancer, ovarian tumors, varicose veins, and abcesses.

What is Galvano-Cautery?

It is the process of cauterization by a resisting wire heated by the galvanic current. The electricity is not applied as in electrolysis, to the body or diseased part, but to the wire only.

What advantage has Galvano cautery over the actual cautery?

The operator with the former has not only a more complete and prolonged control of the process, but he has access to parts and a choice of methods wholly out of the reach of the actual cautery. The wound, too, heals quicker, has less tendency to pyæmia, and all fear of hæmorrhage is well nigh set aside.

What metal is alone suited for use in Galvano cautery, and why?

Platinum is the only metal suitable to this process. Of all the metals, except mercury and lead, it opposes the greatest resistance to the passage of the current, and the greater the resistance the greater the heat.

Does not the proper application of Galvano-cautery require great care in the use and preparation of instruments?

It is obvious that in this department of Electro-therapeutics, the surgeon, who has no experience in diagnosis, no love of detail and no skill or tact in the management of electrical apparatus, would do better in the old ruts of the profession. But with all due allowance, it is not extravagant to write, that after anæsthesia, galvano-cautery is the century's noblest contribution to surgery.

ELECTRO-THERAPEUTICAL APPARATUS.

What Faradic and Galvanic Batteries for Electro-Therapeutical use can be recommended?

Those sold by Hall & Benjamin, of New York, are among the best in use. Their Faradic Battery, No. 1, is chiefly designed for the use of physicians in diagnosis, and cases requiring the ordinary applications of electricity. Battery No. 3, of the same company, is a more complete and powerful instrument, and hence of larger application in a general medical prctice.

How may the value of the Electro-motive Force of the various batteries used in Electro Medicine be comparatively estimated?

The ordinary Daniell element, consisting of zinc and copper, immersed in a solution of sulphuric acid and copper sulphate, yields an electro-motive force, which may be represented by 1.

What then will represent the strength of the Bunsen element?

This element, formed of zinc and carbon, immersed, the one in dilute sulphuric acid, and the other in strong nitric acid, will have an electro-motive force of 2.

What is the Strength of the Chromic Acid element?

This element, zinc and carbon, in a solution of sulphuric acid and bichromate of potash will give a force of 14.

What will represent the Smee Cell?

This cell, composed of zinc and platinum, in solution of dilute sulphuric acid, will yield an electro motive force of 8.

What is the essential quality of a Galvanic Battery for Medicinal purposes?

It is CONSTANCY of action, and this is best obtained in TWO FLUID cells.

Why do the two Fluid Cells best achieve constancy.

Because the arrangement of two fluids effectually presents the polarization of the battery; it depolarizes it.

When is a Battery said to be Polarized?

It is polarized, when there is such an accumulation of hydrogen at the negative plate, and of oxygen at the positive, as to check or anihilate the current.

What other name is sometimes given the Galvanic Battery?

This battery is frequently called the Continuous Current or Constant Current Battery.

What are frequent synonims of the Faradic Battery?

It is often called the Electro-magnetic, the Induced Current or Interrupted Current Battery.

What are the Laws of Dynamic Electricity?

First—The strength of the current is directly as the electro motive force.

Second—The strength of the current is inversely as the resistance.

Third—The resistance is inversely as the transverse diameter of the wire.

Fourth—Force generated by the current is directly as the resistance.

These are Ohm's Laws of Electro-dynamics.

ENGLISH WEIGHTS AND MEASURES.

What must guide the Profession in the use of Weights and Measures?

So long as the United States Pharmacopœia, holds to the weights and measures of the English system, it must be the practical system of the profession in this country.

From what are the Apothecary Weights derived?

From the pound Troy.

What are its Denominations and Symbols?

The pound has the symbol (℔) from the Latin Libra. The (℥) from the Latin uncia. The drachm (ʒ) is from the Latin drachma. The scruple (℈) from scrupulum, and the (gr.) from the Latin granum.

Are the Pound, Scruple, and Drachm used in the Pharmacopœia?

They are all omitted, and weights wholly expressed in ounces and grains.

Are not the Drachm and Scruple used in written Formulæ?

They are; and these symbols have been sometimes so carelessly written, as to be mistaken the one for the other, causing fatal results.

From what are the Measures derived?

From the old wine gallon.

What are their Denominations and Symbols?

Gallon, symbol C. from Latin congeus.

Pint, symbol O. from Latin octarius.

Fluidounce, symbol f℥. from Latin Fluiduncia.

Fluidrachm, symbol fʒ. from Latin Fluidrachma.
Minim, symbol ♏. from Latin minimum.

How are the Ounce and Drachm of this measure distinguished from those of the Weights?

The letter f. is always written before these symbols.

What tables indicate the relative values of the Weights and Measures, respectively?

℔.=	12℥=	96ʒ=	288℈=	5760	grains.
	1℥=	8ʒ=	24℈=	480	grains.
		1ʒ=	3℈=	20	grains.
1 C.=	8O.=	128f℥=	1024fʒ=	61440	*Min.*
	1O.=	16f℥=	128fʒ=	7680	"
		1f℥=	8fʒ=	480	"
			1fʒ=	60	"

Do these Weights and Measures used in Great Britain correspond exactly with ours?

They do not, and physicians in this country should be careful in writing prescriptions from English authorities. They use the Imperial pound and gallon.

In writing a Prescription how are the Quantities expressed?

They are written generally, in the symbols of the Roman table, the fractions excepted.

Are they not sometimes written in the Latin numeral adjectives?

They are, and in order to do this correctly, it is necessary for the student to know something of the Latin language.

Let the following Prescription be written out in both forms.

℞.—Zinci Sulphatis, grana tria.
Aluminis, grana sex.
Aquæ rosæ, uncias duas.
M. fac. collyrium.

In the symbols—℞.—Zinci Sulphatis. gr. iij.
Aluminis, - - gr. vj.
Aquæ rosæ, - - ℥. ij.

The symbol of the denomination is always written before that of the quantity.

How are the Fractional quantities expressed?

The Roman table has no fractions; it is usual, therefore, to express a half by the abreviation (ss.) from the Latin semi, a half. Other fractions are written in the Arabic characters as $\frac{1}{4}$ or $\frac{1}{3}$.

What domestic measures are patients directed to use as equivalents of the ounce, drachm and minim?

The teaspoon as equal to 1fℨ.
Dessertspoon as equal to 2fℨ.
Tablespoon as equal to 4fℨ.
Wine glass as equal to 2f℥.

Are these equivalents strictly reliable?

They are not, and several fatal results have followed this loose method of prescribing powerful drugs.

What should be recommended to families as better and safer?

Physicians would do well to advise families under their care, to provide themselves with a crrrectly graduating glass—American not English.

Is it always safe to prescribe fluid medicines by drops?

This practice is often dangerous; for the value of a drop depends upon several uncertain conditions; temperature, density, shape of a vessel's mouth, and steadiness of hand.

What is Dr. Squibb's method of measuring by drops potent or undiluted liquids?

He introduced for this purpose a pipette

graduated to minims; a little instrument whose convenience commends it to every practioner and family.

What is the action of the Pipette?

It is a small glass tube, open at both ends, and tapering to a point at one extremity. The tapering point being immersed in any fluid, receives a considerable portion of it by capillary attraction, which is retained in the tube by closing the upper end with the thumb. Afterwards, the fluid may be discharged, drop by drop, on the cautious removal of the thumb. This instrument may be bought of any druggist.

The Language and Grammatical Structure of Prescriptions.

Are there good reasons why Medical Prescriptions should be written in the Latin language?

The reasons for this time-honored custom are many and obvious. The Latin is a dead language, fixed forever in its words, rules and structure, yet an object of continued study and acquisition to the educated and scientific in all civilized countries. This it must be as long as human learning shall endure. It is, therefore, a universal language, and eminently fitted to become the vehicle of systems of knowledge addressed to all civilized people. Scientific men labor for the benefit of the race, hence it is proper that they should be able to speak to mankind in a language, as universal as the Latin, and crystalized as it is in classical purity and excellence. These remarks are as pertinent to the Latin nomenclature of science as to the language of prescriptions.

What, therefore, is the Student's first step in the art of elegant and correct prescription writing?

He must first acquire a respectable knowledge of the Latin language. This learning will likewise fit him to study with advantage the whole subject of medicine, both as an art and a science.

What is a Medical Prescription?

A prescription may be given verbally; many a one is written that prescribes no drug, and asks nothing of the apothecary. It may be defined; a formula written or spoken by a physician directing the compounding and administering of medicines, or the use and application of any remedy for the sick. Technically the word requires something to be written, coming from the Latin *præ*, before and *scriptio*, written.

Into how many parts is a Formula divided?

Into five:
First—The head.
Second—The medicines and their quantities.
Third—The directions to the pharmacist.
Fourth—The directions to the patient.
Fifth—The date and signature.

What constitutes the Head?

The letter ℞ marked as it is making it a special symbol. It comes from the imperative Latin verb, RECIPE, meaning TAKE.

How is the second part always written and in what divisions?

The names of quantities of ingredients are always written in Latin.

First—Is the BASIS or the active agent.

Second—The AUXILIARY, promoting the activity of the basis.

Third—The CORRECTIVE, modifying the action of the base.

Fourth—The VEHICLE, to give form and taste.

What old Latin aphorism expresses briefly and pointedly, the design and power of a Formula?

Curare cito, tute et jucunde—To cure quickly, safely and agreeably.

How are the quantities indicated?

Either by weight, as solid, or by measure, as liquid, unless written in the metric system, where all is in weight.

How is the Third part of the Formula written?

The directions to the apothecary are also written in Latin.

How is the Fourth part written?

The directions to the patient are always, in this country, written in plain English. This part is called the s gnature abreviated into S. or Sig. from the Latin, signa a sign.

Should not the directions be written with great care?

The physician will write his instructions full and clear as to dose, time, method of taking the medicine, and any other information important to the patient. Mere verbal directions should not be the rule, and if an ingredient is a dangerous poison, it should be so marked generally.

Should every Formula receive the Physician's signature.

Every prescription should be signed by the writer, and in large cities, even his address and office hours might be added. A little reflection will show the reason for this. The date is, also, as important as the signature. In laying down rules for the guidance of the student here, it must be taken for granted that he has some knowledge of Latin declensions, the rules of syntax,

and the names of the numeral adjectives and adverbs. If he has none, he should go at once to the Latin grammar and learn them.

What is Rule First in the proper structure of a Prescription?

The noun expressing the name of the medicine, is put in the genitive case, if the quantity of it, is also, expressed.

Example—℞.—EXTRACTI OPII, gr. v.

What is Rule Second?

If no quantity is expressed, but only a numeral adjective follows, the noun is put in the accusation.

Example—℞.—Ovum unum.

What is Rule Third?

The quantity is put in the accusation case, governed by the imperative verb recipe.

Example—℞.—Acidi tanici, DRACHMAS DUAS.

What is Rule Fourth?

The adjectives agree with their nouns in gender, number and case.

Example—℞.—VITELLUM OVI UNUM.

The accusative of the quantity can always be avoided by using the Roman symbols. The first rule is in constant use, and increases the importance of the genitive.

What is Rule First relating to the Genitive?

All Latin nouns of the first declension end in a, and form their genative singular in æ.

Example—Jalapa, genitive Jalapæ.

What is Rule Second?

All Latin nouns of the second declension, ending in US, UM, OS, and ON, form the genitive singular in I.

Example—Syrupus, genitive syrupi, Opium,

genitive, opii, Hæmatoxylon, genitive, hæmatoxyli, Scyros, genitive, scyri.

What is Rule Third relating to the Genitive?

All other nouns, important here, no matter what their nominative ending may be, form the genitive singular in s.

Example—Calx, genitive, calcis; sulphas, gen. sulphatis; fructus, gen. fructus; chloral, gen. chloralis.

Greek words from such genitives, as these; asclepias, genitive, aclepiadis; anthemis, gen. anthemidis; hydrastis, gen. hydrastis. But besides hydrastis, there are several other names of common use, which do not change their nominative to form the genitive; as amyl, gen. amyl; azedarach, berbesis; buchu; cajuputi; cannabis: catechu; coca; condarango; cornus; curare; fructus; digitalis; kino; quercus; sassafras; sago; sinapis and spiritus.

What two Rules are important for the formation of the Accusative?

Rule First is, Latin nouns ending in a, of the first declension, are feminine, and form their accusative singular in AM, and the plural in AS.

Example—Pilula, gen. pilulæ, accusative, singular pilulam, plural pilulas.

Rule Second is, Latin nouns of the second declension, ending in UM or US, form their accusative singular UM. The accusative plural of those in US, which are masculine, is *os*, of those in UM, neuter, a.

Example—Ovum, accusative, singular, ovum, plural, ova: syrupus, accusative; syrupum, plur. syrupos.

How do the Adjectives form their cases;

Like the nouns, for Latin adjectives, unlike the English, have declension. Of the numeral adjectives only three of constant use, are declinable; they are unus, one, duo, two, and tres, three.

	Mas.	Fem.	Neut.
Nom	unus	una	unum
Gen	unius	unius	unius
Accu	unum	unam	unum

Nom	duo	duæ	duo
Gen	duorum	duarum	duorum
Accu	duos	duas	duo

Nom	tres	tres	tria
Gen	trium	trium	trium
Accu	tres	tres	tria

In what mood and tense are the verbs used?

In the imperative mood, present tense.

What Prepositions are used in writing Prescriptions?

A few only; they are *ad*, to; *ana*, of each; *cum*, with; and *in*, meaning into. *Add* and *in* govern the accusative *cum* the oblative, and *ana*, a Greek word, the genitive.

What is the Latin Rule for the Ablative case, of the 1st and 2d Declensions?

In the 1st and 2d declensions, the ablative case singular, ends in the 1st in *a*, in the 2d in *o*; the plural of both, in *is*.

Having these few brief rules properly digested, the intelligent student, with a little practice, will be able to write any Medical formula, with elegance and propriety. He should not rest satisfied short of this accomplishment.

The present tendency of the profession, is, decidedly towards simplicity, not only in the

number of the ingredients of a prescription, but in the verbiage of its directions. In Great Britain, physicians still write, both the directions for the pharmacist, and those for the patient in Latin; among us, the directions for the ayothecary alone, are in Latin, and this, for obvious reasons, is a great improvement. I shall, therefore, refer here to such phrases and words, only as are in most frequent use among educated American physicians.

What abbreviated Words and Phrases, beginning with the letter A, are important?

They are:

ad		up to
ad libitum	ad lib.	at pleasure
adde	add	add thou
ana	aa	of each
aqua bulliens	aq. bull.	boiling water
aqua distillata	aq. dist.	distilled water

What beginning with B?

bene		well
bis in dies	bis ind.	twice daily
bulliat	bull	let boil

What beginning with C?

cape	cap	let him take
capsula	caps	a capsule
ceratum	cerat.	cerate
charta	chart.	a paper
cochleare magnus	coch. mag.	a tablespoon
cochleare parvum	coch. parv.	a little spoon
collyrium	collyr	an eye wash.
collutorium	collut	a mouth wash
compositus	comp	a compound
congius	c	a gallon
cortex	cort	bark
cum	cum	with

What beginning with D?

decoctum	decoc	a decoction
dilute	dil	dilute thou
dimidius	dim	one-half
divide	d. and div	divide thou
dividendus	dividend	to be divided.
dividatur in partes equales	d. in p. æq.	let it be divided into equal parts
dosis	dos	a dose

What beginning with E?

emplastrum	emp	a plaster
enema	enem	an enema
extractum	ext	an extract

What beginning with F?

fac	f.	make
fiat	ft.	let be made
fiant (plural)	fnt	let them be made
filtrum	fil	a filter
filtra (verb)	filt.	filter thou
fluidus	flu.	a fluid

What beginning with G?

gargarisma	garg	a gargle
gutta, guttæ	gtt	a drop, drops
guttatim	guttat	drop by drop

What beginning with H?

haustus	haust	a draught
hora	h. or hor	an hour

What beginning with I?

in dies	ind	daily
infusum	inf	an infusion
injectis	inj	an injection

What beginning with L?

lac	lac	milk

lintium............lint........lint
liquor..............liq..........a solution
lotio................lotio.........a lotion

What beginning with M?

magnus............mag.......large
massa..............mass.......a pill mass
misce...............m............mix thou
mistura............mist.........a mixture
mucilago..........mucil.......a mucilage

What beginning with N?

numerus, numero..no..........a number, in number

What beginning with O?

octarius...........o.............a pint
ovum...............ov............an egg

What beginning with P?

pars.................par..........a part
partes equales.....pa æq.......equal parts
parvus.............parv.........small
pediluvium........pdv..........a foot bath
phiala..............phil..........a vial
pilula...............pil............a pill
pulvis...............pulv..........a powder

What beginning with Q?

quantum sufficiat.q. s.........as much as necessary
quaqua hora.......q. h.........every hour

What beginning with S?

saturatus..........sat...........saturated
semissis...........ss............a half
semidrachma......semidr......a half drachm
sesuncia...........sesunc......a half ounce
signa................s. or sig....a sign
sine..................sine..........without
solve, (verb)......solv..........dissolve thou
solutus.............sol............a solution

spiritus	spir	a spirit
suppositoria	suppos	a suppository
syrupus	syr	a syrup

What beginning with T ?

tinctura	tr	a tincture
tere simul	ter sim	rub together

What beginning with U ?

unguentum	ungt	an ointment.

What beginning with V ?

vinum	vin	a wine
vehiculum	vehic	a menstrum
vitellus	vit	the yolk of an egg
vitello ovi solutus	v. o. s	dissolved in the yolk of an egg

What Rule should guide a Physician in writing the abbreviations of a formula ?

He should never so carelessly write, or abbreviate any part of a prescription, as to make it obscure or doubtful.

Example—℞.—Acid. hydro.

Does this mean hydrochloric or hydrocyanic acid? It is exceedingly important to know which one is meant. Dr. Mann says justly: Prescriptions must be written as for the stupidest and most ignorant of apothecaries' clerks.

What is the general Latin Rule for pronunciation ?

In Latin, every word has as many syllables, as it has vowels or dipthongs, and must be pronounced accordingly.

Example—Dilute, as a Latin word, has three syllables, and is pronounced—di-lu-te, and not di-lute, as the corresponding English word.

Cochleare, is pronounced in Latin—coch-le-a-re, and not, coch-le-are, as in English. The Latin, divide, is pronounced, di-vi-de, and not di-vide.

To this general rule, it may be added, that the English system, so called, of pronouncing the Latin, is the most rational for us as English speaking Americans, and, therefore, the sounds of the leading letters in Latin, are nearly the same as in our own language. Hence ch is always hard like k; c and g before a, o and u, are always hard and sounded like k. The same letters before e, i and y are soft; the c being sounded like s, and the g like j. C before the dipthongs æ and œ, is likewise soft.

Let the student convert the following unabbreviated formula taken from the Cyclopœdia of Practice of Medicine, into the abbreviated form with the symbols and Roman characters:

℞.—Extracti taraxici, drachmas duas.
Pottassæ nitratis, drachmam semissim.
Spiritus etheris nitrici, drachmam unam.
Infusi cortisis auranti, uncias sex.

Misce—S. Cochleare amplum bis terre die sumendum.

As everywhere in Europe, the directions here, to the patient are expressed in Latin. The translation is: A tablespoonful must be taken two or three times a day.

The student will, also, convert the following abbreviated prescription from Stlle's Therapeutics into unabbreviated Latin:

℞.—Magnenæ sulph,	- - -	℥ij
Aq. menthæ,	- - -	f℥x
Acet. colchici,	- - -	
Syrupi simpl,	- - -	aa.f℥j
Magneseæ,	- - -	g. CLX

M. S.—Coch. parv. cap.

The following prescription from Dr. Eberle, may be thus written out in both forms:

R.—Carbonat. ammoniæ, - - ℥j
Aq. fontanæ, - - - ℥vj
Mucil. g. arab, - - - ℥ss
Syrup. zingerberis, - - ℥j
M. S.—Tablespoonful three times daily.

The same unabbreviated:

℞.—Carbonatis ammoniæ, drachmam unam.
Aqæ fontanæ uncias sex.
Mucilaginis gumi arabici, unciam semissem.
Syrupi zingerberis, unciam unam.
Misce. Signa. cochleare amplum ter in die.

Does not the Metrical System of the French wonderfully simplify all this?

It does; for it sweeps away at once all the long Latin numerals, all the old English symbols of weight, and the Roman characters. Besides, it relieves the prescription writer of all the Latin rules given above, except those relating to the genitive case, the sound of letters and pronunciation.

		gramma.
Example—R.—	Potas. accetat, - - -	5.
	Spts. æther nit, - - -	6.50
	Tr. scillæ, - - - - -	4.
	Infus. scoparii, - - -	105.

Why is this System called the French Metrical System?

Because near the beginning of the present century, it was first divised and adopted by the French Government, having a fixed value of length, called the meter, for its standard unit.

Apart from its use in Medicine, what are some of its general advantages as a system of Weights and Measures?

It is remarkably simple; twelve words will designate all of its various units of measure and weight; and as in Federal money, which

is also decimal, only a few of those twelve words are ever used in practice. The entire system may be made gravimetric, as it is exclusively in medicine, that is, every object whether solid, or liquid, or gaseous, may be weighed, and never measured. A single denomination, the gram, serves all the purposes of the apothecary, the decigram and milligram being discarded just as the dime and mill, are in writing and reading Federal money. 30.123 grams, is read 30 grams, one hundred and twenty-three thousandths, or thirty grams twelve and three-tenths centigrams, just as it is read in Federal currency 30 dollars 12 3-10 cents.

European pharmaceutists, where this system is well understood, and in constant use, never write, even the abbreviation for the gram, that quantity being the only one recognized, thus vastly lessening the chances of error in writing or compounding formulas.

The milligram, a quantity so much more minute than the English grain, supplies a deficiency ever felt in our system; that is, the necessity of a unit of weight by which may be estimated the smallest quantity of matter, which a physician or druggist can be required to dispense.

The multiplies and divisions of this system, are all decimal, and may, therefore, be multiplied, divided, subtracted and added just as in simple numbers. Simply changing the place of the decimal point, is all that is necessary to reduce from one denomination to another. These are a few of the claims of the metrical system upon the good sense and enlightenment of the age in which we live.

What is the Basis of the Metrical System?

The basis is the meter, a metallic rod, equal to 39.368 English inches, and divided into tenths, hundredths and thousandths.

How are these decimal Divisions named?

The fractional divisions are designated by the word meter, with several Latin numeral prefixes. These prefixes are, milli, centi, deci, derived respectively from the Latin milli, centum and decem.

How are the decimal Multiples named?

These are named by prefixing the word meter with certain Greek numerals. They are deca, hecto, kilo, myria, formed respectively from the Greek meaning ten one hundred and one thousand times the unit.

What are the several units of the system?

The unit of weight is the GRAM; of length, the METER; of surface, the ARE*; of capacity, the LITER.†

What are the fractional denominations of length in full, and their abbreviations?

They are the millimeter, abbreviated mm.; the centimeter, abbreviated cm; and the decimeter, abbreviated dm.

What are the Multiplicative denominations and their abbreviations?

The decameter, abbreviated Dm.; the hectometer, abbreviated Hm.; and the kilometer, abbreviated Km. The meter is abbreviated, m.

What is the Table of Length?

10 mm. (0.001)	make one centim......	0.01
10 cm..........	make one dm..........	0.1
10 dm..........	make one m...........	1.00

*Pronounced like our English verb, ARE.
†Pronounced LEETER.

10 m .... make one Dm 10.00
10 Dm .... make one Hm 100.00
10 Hm .... make one Km 1000.00

How are the Denominations formed in each of the remaining measures?

By the same use of the Greek and Latin numeral prefixes with the respective units.

What are the Denominations and Table of the Weight Unit?

10 milligrams (0.001.) abbre. mg make one centig 0.01
10 cg......................................make one decig 0.01
10 dg......................................make one gram..... ...1.00
10 g..make one Decg.......10.00
10 Dg......................................make one Hectog...100.00
10 Hg......................................make one Kilog....1000.00

What are the Denominations and Table of the Unit of Capacity?

10 milliliters (0.001) abbre. mm. make one centil..........0.01
10 cl......................................make one deciliter......0.01
10 dl......................................make one liter, l... .....1.00
10 l.............................. ......make one decaliter Dl...10.00
10 Dl...................................make one hectoliler Hl...100.00
10 Hl...................................make one kiloliter Kl....1000.00

What are the Denominations and Table of the Measure of Surface?

1 sqr. meter sqm. make one centare, ca.
100 sqr. meters make one are, a.
1000 sqr. meters make one hektare, ha.

The Congress of the United States has legalized the following metrical equivalents:

Meter= 39.37 inches.
Liter = 1.06 liquid quarts=0.908 dry quarts.
Gram=15.482 grains Troy=0.035 ozs. Avoidupois.
Kilo =2.2 pounds Avoidupois.
Are =3.95 square rods.
Stere or (cubic meter)=35.32 cubic feet.

With these equivalents reduction from one system to the other are readily made. But for a proper comprehension of the metrical system, the American student must forget the old units and standards, and think, as it were, only in those of the new. To do this, he must procure, and study actual standards of the metrical measures, as he once studied the yard and foot units of the English system.

What is the usual abbreviation of Kilogram?

It is kilo, a thousand grams, or the weight of one cubic decimeter of water.

What are the Denominations and Table of the Measure of Weight for heavy articles?

10 kilograms make one myriagram, mg. 10.000 g.

10 mg. make one quintal, q. 100.000 g.

10 q. make one ton, t. 1.000000 g.

The ton is equal to one cubic meter of distilled water=1.000000 g.

The kilo is equal to one cubic decimeter of distilled water=1000 g.

The myriagram is equal to ten cubic decimeters of water=10.000 g.

The gram is equal to one cubic centimeter of distilled water=to one milliliter.

The liter is equal to one cubic decimeter of distilled water=to one kilo=1000 g.

How does the Metrical System simplify the operation of finding the Specific Gravity?

In this system, as just stated, the weight of a liter of water at its maximum density, 39 F. is one kilogram; hence the weight, in kilograms, of a liter of any liquid, or of a cubic decimeter of any solid, is the same as the specific gravity.

What, again, is Specific Gravity?

It is the weight of any solid or liquid compared with the weight of an equal volume of water.

A liter of pure water, weighs a kilográm, or 1000 grams; but the liter is also a cubic decimeter; therefore, when a liter of any liquid is measured, or a cubic decimeter of any solid is weighed, its specific gravity is obtained as well. Besides, it is often desirable to ascertain the weight of a large mass, which can be measured but not weighed; or to find the bulk of some irregular solid, which can be weighed, but not measured. The specific gravity being obtained or given, such problems can be easily solved.

Examples—A liter of alcohol weighs 835 grams; what is its spe. gr.?

Apply the rule; divide the weight of the alcohol by that of a leter of water; 835÷1000 =.835—Answer.

A centiliter of pure mercury weighs 140 grams, what is the spe gr. of pure mercury?

A centiliter is the hundredth of a liter; hence a liter will weigh 100x140=14000 grams or 14 kilograms—Answer.

What is the spec. gr. of the water of the Dead Sea, if five liters of it weighed 6k. 2, that is six and two-tenth kilograms?

One liter will weigh the fifth of 6k.2=1.24 grams—Answer.

Three liters of whale oil weighs 2k. 769, what is its spe. gr.?

One liter must weight the third of 2k.769= 0.923—Answer.

A block of white pine is 60 cm. long, 15 cm. wide, and 10 cm. thick, and weighs 3k.762, what is its spe. gr.?

The solid contents are 60x10x15=9000 cu. cm., but a cu. cm. is one-tenth of a cu. dm.; hence 9000 cu. cm. are equal to 900 cu. dm. and 3k.762÷900=one cu. dm. of the block, 0.418—Answer.

What will four liters of honey weigh, if its spe. gr. be 1.456?

The four liters, will, of course, weigh four times 1.456=5824 grains=5k.824—Answer.

What is the weight of 91.4 of ammonia water, its spe. gr being 0.875?

The 91.4 will weigh, 9.4x.875=8.2250=8k.225—Answer.

A walnut plank has a spe. gr. of 0.681, what will a plank weigh 3m. .5 long, 62 cm. wide, and 10 cm. thick?

The solid contents are—3.5x62x10=2170 cu. cm.; hence 2170=217 cu. dm.; but a cu. dm.=1000 grams; therefore, 0.681x217=147.777 grams =147k.777—Answer.

The great bell in the French Cathedral at Montreal, weighs 11263k.6, if its spe. gr. is 8.7, how many cubic decimeters does it contain?

It is plain that it will contain just so many as 8.7 is contained times in 11263.6=1294.66+ cu. dm—Answer.

Can anything be plainer or simpler than all this? Keeping in view the definition of specific gravity, it may be, also, said that the same number expresses in the metrical system, both sp. gr. and the weight of one cu. cm. of pure water at the temperature of 39.2 F. This weight is one gram, so that the weight of one cu. cm. of any substance, at that temperature, expressed in grams, is the same as its spe. gr.

What important distinction is it necessary to observe here again?

The difference between spe. gr. and density. Spe. gr. is mere ratio; it conveys no other meaning than the relative, abstract number which expresses it. Water being one, iron weighs 7.8; seven and eight-tenths of what? Density, on the contrary expresses, water or any other substance being one, an absolute division or multiple of the fixed value of the standard unit.

What then is the admirable point here, in the French System?

It is that they have taken the same unit, one cubic centimeter of pure water, to express both the unit of volume and the unit of weight. The same number, therefore, which expresses spe. gr. expresses density as well. It is this principle that makes it possible and easy as above, to obtain spe. gr. from weight, and weight from spe. gr. and volume from both, as in the following example:

An ingot of copper of spe. gr. 87.9. weighs 348g. 963 how many cu. cm does it contain?

Since the spe. gr. of the copper is its weight compared with a cu. cm. of water, it must contain just so many cu. cm. as 8.79 is contained times in 348.g. 963=39.7 cu. cm—Answer.

No such convenient arrangement is found in the English system of weights and measures. It is true that a cubic inch of pure water is taken as the standard or unit of weight, but the same unit is not likewise the standard of volume.

Is not this principle, also, one of the most notable features of the New Chemistry?

This characteristic of the New Chemistry, chiefly distinguishes it from the old. The same

principle has been introduced there, except that hydrogen gas is the standard unit instead of water or air.

It is still convenient, however, in Chemistry, to refer occasionally to air as the unit in spe. gr. but hydrogen gas, at the temperature of 0°C. and the pressure of 760 mm. is the Chemistry standard for spe. gr. and density, the latter, as explained above, being an absolute value from the fixed value of the standard unit, while the former is mere ratio.

What is the name of the Standard Volume of Hydrogen in Chemistry?

It is called the CRITH, a criterion or standard from the Greek *Kritas* a judge.

What quantity of Hydrogen constitutes this unit?

One liter which weighs, 0.0896 grams. This is the CRITH.

What are the Density and Spe. Gr. of Hydrogen in Chemistry?

Its density is 1; its spe. gr. referred to air is 0.0693. 1 as a number, expressing ratio, may be also, regarded as its spe. gr. in the chemical sense, for it may be taken abstractly, and not as the crith. But it is agreed to restrict the word density to mean the actual weight of a gas referred to the hydrogen ATOM as a standard.

What is this Standard called and why?

It is called the MICROCRITH, or the LITTLE CRITERION; and is so named, because it is just one-half the crith, which represents, always a molecule or two atoms of hydrogen.

What is the Molecular Weight of any Gas?

It is the weight of one liter of that gas, compared with the hydrogen liter or crith, and

represents, therefore, the weight of two atoms of it.

What then is the relation of Molecular Weight to Density?

Since molecular weight represents the weight of two volumes, and density one, the density of any perfect gas is the half of its molecular weight. This is the same as to say, that the weight of one liter of the gas, divided by the crith, or 0.0896 grams gives its density.

The first method is by calculation, the second by experiment.

Example—The molecular weight of water is 18; this number divided by 2, gives 9 as the density of steam. Again, let a liter of steam or water gas, be weighed; it is 0 8047 grams; divide this number by the crith, or 0 0896, and the result, as in the first case, is 9, rearly. These processes inform us, that steam is nine times as heavy as hydrogen; and this, in the case of any gas, is its density.

What is the converse of this Principle?

Knowing density, molecular weight is obtained by simply doubling it.

What is the importance of density in an Analytical point of view?

It is necessary in any case, in order to ascertain the true molecular weight.

In these investigations, what does mere Analysis of any homogeneous substance give only?

It gives certainly only the ratio of its constituents, and not their absolute weight of volume. Hence analysis, may or may not yield the true density of the substance.

If a liter of the substance, in the form of gas, could be obtained and weighed, would that clear away all doubt?

Yes; were a liter of its vapor once accurately weighed, then all uncertainty in regard to its density, as has been seen, and all that depends upon density—molecular weight, molecular volume, specific gravity and atomic weight, would be at an end.

Example—Water may be taken again; the analysis of water shows that in 100 parts of it, there are 11 11 of hydrogen to 88 89 parts of oxygen,* which numbers reduced to their lowest terms give the ratio 1 to 8. Is 8 the density, or actual weight of an atom of oxygen referred to hydrogen? The Old Chemistry said it was, because its atomic weights were mere ratios, and of density it knew nothing. But 2 and 16, 3 and 24, 4 and 32, and 5 and 40, all have precisely the same ratio—1 to 8. Which of these several sums is the true density of water? Analysis, obviously, makes no certain response.

The question was decided above, by experiment, when the weight of a liter of steam was divided by the crith.

Knowing the Crith, as the weight of a cu. cm. of pure water is known in the French metrical system, may not, as seen there, spe. gr. density, molecular weight, and molecular volume, be readily ascertained?

The weight of a liter of any substance in vapor, referred to hydrogen, is its density; the double of this number is the molecular weight. The same number which expresses density, gives the specific gravity, referred to hydrogen, also the molecular VOLUME, since it is referred to a molecule of hydrogen, and besides, as will be seen in its proper place, the atomic weight of the same substance.

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*18:16::100:=88.89. 18:2::100:=11.11.

Example—A liter of oxygen gas weighs 16 times the crith; 16 is, therefore, its density; and 2 its molecular volume; twice 16 or 32 its molecular weight; 16 is also, its spe. gr. referred to hydrogen and its atomic weight.

Knowing the Specific Gravity of Hydrogen referred to air, may not the spe. gr. of any other substance be easily obtained?

The spe. gr. of hydrogen referred to air is, 0.0693; it is plain, therefore, that if this number be multiplied by the DENSITY of any other substance, the product must be the spe. gr.

Example—The density of oxygen is 16, what is its spe. gr.? 0693x16=1.01—Answer.

What is the Specific gr. of Chlorine?

The density of chlorine is 35.5, hence 0.693 x35.5=2.46—Answer.

What is the spe. gr. of Mercury?

The density of mercury is 200; 200x.0693=13.96—Answer.

Such are a few of the admirable simplifications in the principles and methods of the New Chemistry.

Metrical Pharmaceutical Weights Compared with the English.

It is best, of course, for younger pupils to study and master the Metrical System without any reference to the units, and standards of the one, yet in use in this country; but as this is impossible for the greater number who may study these pages, it is expedient to append, here a comparitive view of the values of the two systems.

In the Metrical System, we have no other quantity to consider, than the gram and its fractional units.

1* grain=.06 grams. 1 ounce=31 grams.
1 scruple=1 30 grams. 15 grains=1 gram.
1 drachm=4 grams.

What is the Rule for converting any quantity in English weight, into Metrical grams?

The previous table suggests it. Reduce the quantity to grains, and divide by 15, the number of grains in a gram.

What is the Rule for a similar reduction of the higher denominations?

Reduce the quantity to drachms, and multiply by 4 or reduce it to ounces and multiply by 31. One gram of water is equal to 16.2 minims, and the same rules are applicable nearly in the conversion of fluid measures into grams.

What is the Table of Fluid equivalents?

1 *M* or minim=.06 grams.
1 fʒ=3.75 grams.
1 f℥=30. 00 grams.

Having the above tables and rules, may not any common formula be readily converted into gram weights?

Let the student change the formulas on pages 86 and 87 into metric weights.

℞.—Magnesæ sulph, - - ℥ij=62 grams.
Aq menthæ, - - f℥x=300 grams.
Acet. colchici, - -
Syrupi simpl, - - aaf℥j=30 grms.
Magnesiæ, - - - gr CLX =10.6 grams.

℞.—Carbonat. ammoniæ, - - - ʒj=
Aq. fontæ, - - - - - - - ℥vi=
Mucilag g. arab, - - - - ℥ss=
Syrup. zingerberis, - - - - ℥j=

*These quantities are a little less than the real values.

What is the Rule for converting any number of grains, whether fractional or entire, into equivalent expressions in grams?

We have seen that 1 grain is equal to .065 grams; hence multiply this number by the number expressing the grains, and the result will be the grams.

Example—40 grains are equivalent to what number of grams? .065x40=2.60—Answer.

1-64 of a grain is equivalent to what in grams? .065x1-64=.001—Answer.

By this rule, a pupil can in an hour, construct and paste up in his room a table that will save him much after trouble. When he reaches 20 grains, let him mark it also, 13, 60 grains, 13 and 120 grains, 23.

In order to change liquids into equivalent gram weights, some regard must be had for the difference of spe. gr. But this can be readily cleared up, and made easy in practice.

What Liquids of the Pharmacopœia are lighter than water?

They are tinctures, spirits, comp. spirits of ether, sweet spirits of nitre, and fixed and volatile oils.

What Liquids are heavier?

These are syrup, glycerine, a few fluid extracts and chloroform. Among the fluid extracts, Dr. Squibb includs squills, liquorice, wild cherry, aconite and cubebs.

What Liquids are nearly or quite the same in spe. gr. with water?

They are waters or liquids generally, decoctions, infusions, most fluid extracts and tinctures in dilute alcohol.

What table expresses these differences of spe. gr. for the minim of grams?

Apothecary's Mea.	Grams. Spe. Gr. of water.	Grams. Lighter than Water.	Grams. Heavier than water.
1 *Min.*	.06	.055	0.8

By what Rule then can a minim of any liquid be reduced to equivalent weight in grams?

If the given liquid be of the same spe. gr. with water, multiply the number expressing it by .06; if lighter than water by .055, and if heavier, by .08.

What is the weight in grams of 8 minims of a liquid lighter than water? 8x.055=.45—Answer.

Let the student construct for his use, a convenient table from these data. At 60 minims, he will mark 1fʒ, and at 250, f℥ss. It will be observed that the metric system in its application to Pharmacy is purely gravimetric; that is it weighs every thing and measures nothing. In every country where it has been adopted, it is customary to weigh not only solids but liquids as well. The adoption of the gravimatric, in place of the present mixed volumetric and gravimetric methods, should go hand in hand with the adoption of the metric system.*

It is quite probable that the next United States Congress will adopt and legalize the metric system, hence the greater necessity for its careful study. The pupil would do well to provide himself with the following apparatus: Several straight rods, 20, 30 or 50 centimeters long; a few pieces of tape, 2 or 3 meters long; a cup and a basin; a little dry sand, and several stones of a kilo, and half, fifth and tenth kilo

*Louisville Medical News.

weight. A small balance would, also, be quite useful.* With these, he could soon familiarize himself with the concrete values of the units of the system; for, after all, this is the chief difficulty in the way of its general adoption.

When we speak, for example, of a meter, we have, first, the novelty of the name to confuse us, and yet more, in the fact, that no conception enters the mind from experience, as to what a meter's length really is. The same remark is true of all the units of the system; but with the use of the apparatus, described, clear, and correct notions of these standards are soon acquired.

The names, which make up the simple nomenclature of our system of Federal money, and for which the country is under lasting obligations to the practical mind of Thomas Jefferson, of Virginia, were, once, no less strange to us, than are, now, those of the French system of weights. Mill, cent and dime, have a kindred form and origin, with milli, centi and deci; but joined, as they are, to the admirable decimal system whose values they bear, the good sense of the people soon approved them, and now what citizen would desire to exchange it for the clumsy system which our fathers brought with them from the mother country?†

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*Bulletin of the American Metric Bureau.

†The subject of Metrical Weights and Measures, as a universal system, has been treated in a masterly manner, in a letter addressed to Mr. A. H. Stevens, by Mr. Samuel Barnett, of Washington, Ga., a gentleman, whose acuteness of intellect and admirable, moral and social worth, merit the highest honors of his State.

LIGHT AND OPTICS.

CATOPTRICS AND SOURCES OF LIGHT.

What is a general Definition of Light?

It is that physical agent by which we are enabled to see.

What is Optics?

It is that branch of Physics which treats of the properties and laws of light.

How did the Ancients regard Light?

They believed that light was, in some way, produced in the eye, and its emission, thence, caused vision.

What is the modern Belief?

That light exists independent of the eye, and that something coming into the eye from without excites the sense of vision.

What does the Pentateuch say of Light?

"And the earth was without form and void, and darkness was upon the face of the deep, and the Spirit of God moved upon the face of the waters, and God said let there be light, and there was light, and God saw the light that it was good, and God divided the light from the darkness."

So that whatever light is, whether a form of motion or a material substance, it had its existence before any eye was formed.

What are the Sources of Light?

The sun, stars, chemical action, electricity and phosphorescence. All bodies are either luminous or non-luminous.

What are Luminous bodies?

They are bodies in which light is generated, and from which it is emitted independently of all others.

Example—The sun and a candle.

What are Non-Luminous Bodies?

These are bodies, which shine only, as they are shone upon, as the moon. They may be called illuminated bodies.

What is a Transparent Body?

It is one, which like glass, does not arrest the passage of light.

What is an Opakque Body?

It is a body whose molecules arrest the rays of light in their passage, as the metals.

What is the Law of the distribution of Light?

From whatever source it eminates, it moves in straight lines. The lines along which it moves are rays of light, and these rays form a cone, whose base is the pupil of the eye, and whose apex is on the object seen.

This is the Divergence of Light; what is its Law?

The surface over which, in any case the base of the cone is diffused, increases as the square of the distance increases. That is, if a lamp illuminates from a window four square feet of a wall in front of it, at twice the same distance, it will illuminate four times the space or sixteen square feet.

What is the Law of the Intensity of Light?

The intensity of light, as it goes out from a luminous point, diminishes as the square of the distance increases. That is, at a distance of two feet, the intensity will be only one-quarter of what it is at one foot.

What is the Velocity of Light?

The velocity of light, as determined by Rœmer, from the eclipses of Jupiter's moon, is 182,560 mi es per second. M. Fizeau, by experiments over terrestrial distances, found it to be 194,677 miles per second. Bradley, in 1723, in Kew Gardens, England, discovered the aberration of light, and thence the velocity of light, to be 161,515 miles per second.

What is the Aberration of Light?

"If we move quickly through a rain shower, which falls vertically downward, the drops will no longer seem to fa l vertically, but will appear to meet us. A similar deflection of the rays of light from the stars by the motion of the earth in its orbit, is called the aberration of light."

How is the Velocity of Light calculated from this?

It is the solution of a simple prob'em in plain Trigonometry. Knowing the speed, at which we move through a shower of vertical rain drops, and knowing the angle, at which they appear to descend, we can readily calculate the velocity of the falling drops. Hence knowing the velocity of the earth in its orbit, and the angle, at which the rays of stellar light appear to bend towards us by that motion, the velocity of light is easily calculated.*

What is Photometry? †

It is the measurement of light.

How may the difference in Intensity of two or more d fferent Lights be ascertained?

This process is based upon the law of intensity already given, and the fact that the more

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*Prof. Tyndall's Notes on Light.

†From Phos, Light and Metron, measure—Greek.

intense a light is, the darker will be its shadow.

Let the shadow of a walking cane be cast upon a white screen by means of a flame placed behind it; and let another flame be placed beside the first; a second shadow will appear close to the first. Now if the two flames have equal intensity, these shadows will be equally dark; if not, let the more intense flame be moved back till the shadows do exactly correspond in depth. If the two distances be now measured, and their numbers squared, we will have a numerical expression of the relative intensity of the two flames. Suppose the numbers to be 2 and 4; then the relative intensity is as 4 to 16.

What is Catoptrics?

Catoptrics* is that branch of Optics, which treats of reflected light.

What is the Reflection of Light?

When a ray of light strikes any surface, which causes it to rebound in another direction, it is reflected. If it be not reflected, it is either in part absorbed or transmitted by the surface. If the surface is polished, it will be regularly reflected; if not, the light will be scattered.

What is the Law of Reflection?

The angle of reflection is always equal to the angle of incidence. Upon this law, hang all the phenomena of optics.

What is a Mirror?

It is any polished surface which powerfully reflects light. There are three kinds, plane, concave and convex mirrors.

*From the Greek, kata down u'pon, and optomai to look.

When does a Mirror* reflect most light?

When the angle of incidence is most oblique. A basin of water and a candle will illustrate this; as the same with a plumet line suspended from a cross piece graduated in inches will demonstrate the law of reflection. The scale runs from zero, the point of suspension, in opposite directions.

What is an Image in Optics?

It is a figure of any object formed by reflected rays proceeding from every point of it.

In what direction is an Image always seen?

An image is seen in the direction of the rays which proceed from it. Oblique rays show an image on one side of the mirror, and as far behind as the object is in front of it. Perpendicular rays are reflected back along their own course, and show an image directly behind the mirror.

Are there not two Primary Reflections from every mirror?

An oblique reflection shows a series of images over-lapping each other, and if it is very obl que and the glass thick, these images may be quite separated. The first image is from the reflection of the light from the anterior surface of the mirror; the second, and the brighter one, is from the reflecting surface of the amalgam at its back.

The other images of the series are formed by the reverberation of the light from surface to surface of the mirror. The larger the incidences, the brighter the reflections from the amalgam surface, and the less those from the glass.

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*A looking glass and a candle will afford the pupil many interesting experiments in this connection.

In what respect will an Image always differ from its object?

The image must present a LATERAL INVERSION of the light. Hence any piece of composition in type may be read in a mirror as the same matter on the printed page.

What interesting Phenomena seen in plane Mirrors are all the consequence of the law of reflection?

First—A plane mirror, one-half the height of an object, gives a full height image of the object.

Second—A plane mirror moving parallel with itself, will cause an image to move with twice its velocity.

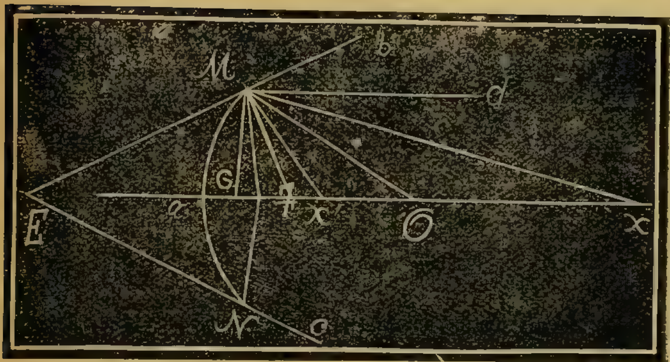
Third—A plane mirror made to revolve, the angle described by the image, will be twice that described by the mirror.

Fourth—If a plain mirror be inclined at an angle of forty-five degrees, the image of an object erect, appears horizontal, while the image of one horizontal appears erect.

Fifth—If an object be placed between two mirrors forming an angle with each other, a number of images will appear; and the number will increase as the value of the angle diminishes. This is the principle of the kaleidoscope. To find the number of images, divide 360, the number of degrees in a circle, by the value of the given angle. When the angle is zero, then the nnmber of images is infinite. It is usually 60° the sixth of the circle.

Does the same Law of Reflection apply to Concave and Convex Mirrors?

They have the same law; and by them rays from all terrestrial objects may be made parallel or convergent; they are naturally divergent.



Let MN be a portion of the circumference ence of a circle, having its centre at O. Let the line ax, passing through the centre, cut the arc M N, at *a* in two equal parts Now imagine the curve MN to be revolved around the line *ax* as an axis. It would describe the segment of a hollow sphere, whose inner surface, when polished, is a concave mirror. All parallel rays, such as come from an infinite distance or from the sun, as dM, are reflected from the mirror along the line M F, and made to converge at the point F, half way between the mirror and the centre O. F is, therefore, called the principal focus of such a mirror, or the focus of parallel rays.

Let a candle be placed in that focus, then reciprocally, the rays will be reflected parallel along M d, and go out without forming an image, for they converge in no focus. Let the candle be placed at the centre O, then the rays will be reflected back along the same line M O, for the reason, again, that by the law, the angle of reflection is equal to that of incidence.

If the candle be placed at the point x, beyond the centre O, the reflection will be along the line M$\dot{x}$, to $\dot{x}$, a point between the centre O and F, where the image will appear. If reversed, as before, the image will appear at x. Now let the candle be placed at the point G, between the mirror and the principal focus, and the rays of reflection will go out, as along the lines M b and N c, divergent, and will form no image before the mirror, but a virtual image behind it, at the point E. The image, here, is said to be virtual, because at the point E the rays appear to converge; and it has been remarked, that objects are always seen in the direction of the rays which reach the eye.

When an image is formed behind a concave mirror, it is always erect and magnified in proportion as the object approaches the focus F. When an object is further from a concave mirror than its true focus F, the image will be inverted, and smaller than the object, if the image fall between F and O, greater if beyond O.

REFRACTION—THE LENSES.

What is Refraction of Light?

When light passes through one medium into another, as from air into water, instead of proceeding in a straight line, it is bent out of its course. This is refraction.

What is the law of Refraction?

When the rays pass perpendicularly through one medium into another, they move in a straight line; when obliquely through a rarer into a denser, they are bent generally *towards* a

perpendicular to the surface; but when they pass through a denser into a rarer medium, they are generally bent *away* from the same perpendicular.

This important optical law is thus expressed mathematically: *The sine of the angle of incidence, divided by the sine of the angle of refraction, is a constant quantity.* In this form the law is invariable.

Why is it modified above by the word generally?

This is best explained by an example. It is a notable fact that refraction by spirits of turpentine is greater than that by water, though the density of turpentine to that of water is 874 to 1000. A ray, however, passing obliquely from the spirit into water, is bent *from* the perpendicular; while a ray passing from water into turpentine, is bent *towards* the perpendicular. Hence the reason of the use of the modifying word generally.

What are the Indices of refraction for water and other familiar substances?

The index of refraction for water, is 1.336; of vinegar, 1.334; of brandy, 1 360; alcohol 1.372; of turpentine, 1.605; of bisulphide of carbon, 1.678, and of the diamond, 2.439.*

What is the principle of REVERSIBILITY in Refraction?

It is that result of the law, which restores the ray, after a series of refractions, to its original direction in its first medium. This is seen, every day, in the natural appearance of objects through window panes.

What familiar effect has refraction upon water, or any transparent plate?

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*Tyndall.

It makes them to appear shallower or thinner than they really are.

What is the relation of Refraction to Reflection?

They constantly go together; when one ceases the other ceases also.

What is the Law of this relation?

The higher the refractive index of any substance is, the greater is its power of reflection. This is the cause of the unrivaled splendors of the diamond.

What chemical relation has Refraction?

The power of refraction, is the only property of matter, except weight, which is unaltered by chemical combination. The physical law is: the greater the density, generally, the larger the refractive index.

What is the comparative value of the refractive index of a Gas?

It is very small, and in consequence gases both reflect and refract light feebly. The refraction of the atmosphere has, however, to be taken into account by astronomers and engineers.

What is a Lens?

It is any refracting substance, bounded by curved surfaces.

How are Lenses classified?

They are studied in two classes:

First—Those which render parallel rays convergent.

Second—Those which render the same rays divergent. There are three kinds in each class.

What are these?

CONVERGING LENSES.

First—Double convex.
Second—Plano-convex.
Third—Concavo-convex (Meniscus).

DIVERGING LENSES.

First—Double concave.
Second—Plano-concave.
Third—Concavo-concave.

What is the principal axis of a Lens?

It is a straight line drawn through the centre of the lens and perpendicular to its two convex surfaces.

What is the principal Focus of a Lens?

All rays falling upon the lens, parallel to the axis, are made to intersect at a point on the axis behind the lens. This point is the principal focus, and is the focus of parallel rays.

How does the convex lens, as in the case of the concave mirror, become a BURNING GLASS?

It does so in virtue of its power to converge parallel rays to a focus, concentrating, thereby, on one point a high degree of temperature. A lens of this sort is capable of instantly fusing the metals and liquefying quartz and flint rock.

Do Convex Lenses form Images?

They form images in their foci in the same way as do concave mirrors.

Why are these Images always inverted?

Because the rays of light in passing from the several points of the object, cross each other before they meet in the focus.

Why do Convex Lenses magnify?

Because in virtue of their power to make rays converge, these after refraction, seem to enter

the eye from points more distant from each other than they really are.

Why can not a Spherical Lens bring all the rays that fall upon it, to the same focus?

Because the rays which fall upon or near its circumference, are more refracted than those which pass through its central portions, and are, therefore, brought to an earlier intersection. This difference of focal distance between the central rays and those of circumference, is SPHERICAL ABERRATION of the lens.

What is an Aplanatic Lens?

It is a lens composed of two or more lenses of different curvatures, neutralizing aberation.*

What is the Human Eye?

It is a compound lens, in three parts; the AQUEOUS HUMOR, the CRYSTALINE LENS, and the VITREOUS HUMOR.

Why does the Pupil of the Eye always appear black?

For two reasons:

First—Because of the internal black coating of its posterior wall.

Second—Chiefly, because we are not able ordinarily, to see the spot of illumination when it is illuminated, since, as has been constantly exhibited in all reflection and refraction, the principle of REVERSIBILITY comes into play. The rays on returning from the bright spot, must by this principle, intersect to form their focus or image in the source of illumination; hence the impossibility of seeing the illuminated spot, unless the eye of the observer, be placed between the pupil and the source of illumination; but this cuts off the rays of light. There is a device

*Aplanatic from the Greek *a*, privative, and *planasthac*, to wander.

by which this difficulty can be obviated. Let a small hole be pierced through a mirror; the eye can now be strongly illuminated, and, at the same time, observed through the orifice from the back of the mirror. This is the Ophthalmoscope, one of the most important contributions to Surgery of the age. Under this instrument the interior of the eye glows like a coal of fire.

Why does the eyes of Albinos and White Rabbits appear red?

Because the black pigment is wanting and the pupils are seen by light, which traverses the SCLEROTICA. Cut off this light and their pupils are black.

What admirable Instrument was modeled from the eye?

The eye is a Camera Obscura,* with its refracting lenses. The ground glass of the Camera on which its images are pictured, is its retina.

Since images on the retina are inverted, why are objects always seen erect?

Because the eye is so constructed, that every point of an image painted upon the retina, is seen in a DIRECTION PERPENDICULAR TO THE POINT OF THE RETINA ON WHICH IT FALLS. And, hence, it is absolutely necessary to have an INVERTED picture of an object on the retina, in order to see it erect.

What conditions are necessary for perfect vision?

That the object should be placed before the eye, and that the rays of light reflected from it, should form a perfectly defined image upon the retina.

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*This beautiful piece of mechinism should be carefully studied by the pupil.

Why are some persons Far-Sighted?

Because in many old people, and some youth, the axis of vision is too short; that is, the distance from the centre of the cornea to the retina. In this case the image is formed *behind* the retina instead of *upon* it.

Why are some persons Near-Sighted?

Because in many young people, and some old, this same axual distance is too long. In this case, the image is formed BEFORE the retina, instead of upon it.

In near-sight, the defect is remedied by holding the object very close to the eye, so as to increase the divergence of the rays; hence the popular name.

In far-sight, it is remedied, habitually, by holding the object some distance from the eye, so as to lessen the divergence.

What is the artificial remedy for Near-sight?

It is remedied by placing before the eyes, a concave glass or lens. This augments the divergence to the necessary degree.

What for Far-sight?

By placing before the eyes, a convex lens, which sufficiently lessens the divergence.

Why do Drunkards and Cross-eyed people see double?

Because they are unable to fix the optical axes upon the same point or object, so as to convey but a single impression to the brain.

What is the Angle of vision?

It is the angle at the eye subtended by any object of vision. The larger this angle, the greater the size of the object. Distance, also, affects this angle.

Is the Eye a perfect optical instrument?

It is not; it is frequently defective from spherical aberration. A confused scattered light always exaggerates the images of luminous objects upon the retina. It is this, that causes the crescent moon to appear larger than the sphere to which it belongs.

Can the Eye see objects in itself?

It can; the well known *muscæ volitantes*, are images of this kind. They are caused by opaque bodies flecking the humors of the organ; and these would be a constant source of annoyance, if less light reached the retina through the pupil. The flood of light obliterates their shadows.

What is a Microscope?

It is an instrument, which so magnifies minute objects, as to make them distinctly visible to the eye. It effects this by enlarging, as has been exhibited, the angle of vision under which the object is viewed.

How many kinds of Microscopes are in use?

There are two; the simple and compound. In the first, the object is viewed directly, either by a simple or compound lens; in the second, a magnified image of the object is first formed, and this again, is viewed with magnifying lenses.

How is the Instrument usually constructed?

The simple microscope is usually a tube containing a single double convex lens. The compound microscope contains, in addition, another double convex lens, which magnifies the image formed by the first lens These are called, respectively, the object and eye glasses.

An illuminating mirror, is also a common adjunct of the microscope.

What is a Stereoscope?*

It is an optical instrument by means of which, a picture on a flat surface, appears to stand forth as a *solid.*

What is the principal of its action?

It was first ascertained that the images of an object within the two eyes, are different from each other. We can see only one point of an object d stinctly, at a time; now if these two different sides of the object are so laid before the view as to be taken in at once, the effect is the visual impression of a solid.

What is a Pr:sm?

Any body of glass having two plane surfaces not parallel, is a prism.

What is the action of the Prism?

On looking through a pri-m, all objects appear to be removed out of their true places. Why is this? it is because its planes are not parallel. It was seen in another place, that when we view objects through a pane of window-glass, they all appear natural. Why is that? It is because the sides of the pane are parallel, and in this case the *reversibility* of refraction follows; that is, the rays recover, on emergence, the precise direction they left on their first refraction from the air.

The ray in the prism is *permanently* refracted.

How did the Prism, in the hands of Newton become an exceedingly valuable instrument?

By means of it he revealed the mysteries of

* From the Greek, stereos solid and metron, measure.

solar light, and opened the way for the discovery, in our time, of Spectrum Analysis.

What is Dispersion?

When solar light is sent through a prism, its constituent rays are drawn asunder. This separation of the elements of light, is called *dispersion*.

What is the cause of Dispersion?

Luminous bodies generate in ether waves of various length; some are shorter than others. In passing through the prism, the short waves are more retarded than the longer ones and hence are more refracted. The result is separation or dispersion.

What is a Spectrum?

It is the luminous image of white light formed by its decomposition in the prism.

What is the Solar Spectrum?

When the white light thus decomposed, comes from the sun, the image is the solar spectrum.

Of what does the Solar Spectrum consist?

It consists of a series of vivid colors, which, when again blended, produce the original white light.

What are those colors, and their order in the Spectrum?

Beginning with the one least refracted, they are RED, ORANGE, YELLOW, GREEN, BLUE, INDIGO, and VIOLET.

What determines the color of these elements of white light?

It is determined in each case, solely by the wave length. The gradation diminishes from red to violet.

What are the extremes of this scale of wave lengths?

The length of a wave of red light, is nearly

$\frac{1}{39000}$ of an inch, of a wave of violet about $\frac{1}{57500}$ of an inch.

How many waves of Red Light enter the eye in a second?

As many as the product of 39000 by 186398, the velocity of light.

How many of Violet?

The product of 186398* by 57500.

How is Color related to Sound?

It is to light, what pitch is to sound.

Is the Spectrum confined to its visible limits?

It extends considerably beyond in both directions. Above the violet is a great body of rays, having no heat or light force, but powerfully endowed for chemical action; and beyond the visible red, are rays without light force, but of high heating power.

What gives Color to objects around us?

All bodies absorb light, but this capacity is selective; some rays of the spectrum are absorbed while others are rejected. This gives variety of color.

Where does the color of a body reside, on its surface, or in its interior?

It reflects white light, always from its surface. The color comes from the extinction of certain rays within the body.

What is Chromatic Aberration?

Like "Spherical Abberration," it is due to irregular refraction. A spherical lens is incapable of bringing its different colored elements to a common focus

*Since giving the velocity of light on page 105, Mr. A. A. Nicholson, of the United States Naval Academy, has made a new determination of the velocity of light, by means of a lens of 150 feet focal distance. The result is 168,396 miles.

Has this been corrected by Opticians ?

Chromatic aberration was believed by Newton, to be an insuperable difficulty in practical optics. The problem was to produce refraction without dispersion, and therefore, decomposition of light. He thought that dispersion must ever be exactly proportional to refraction. This is now known to be untrue; and even lenses are constructed, which refract and are achromatic.*

How is this affected ?

By so combining a convex crown glass lens with a concave flint glass lens, as to neutralize on refraction, the dispersive effect of the convex lens. The RESIDUAL refraction is achromatic.

Was this discovery of great importance in the construction of the Telescope and Microscope ?

Previous to this, it was impossible to produce either of these instruments in their present comparative perfection.

What are Subjective Colors ?

They are colors, which have their origin in the peculiar condition of the eye, and not in the external conditions which produce the sensation of color.

What is Daltonism?

It is the *color blindness*, which is now known to afflict so many people, disqualifying them for positions that require quick discrim nation between colors, as engine drivers. John Dalton was unable to distinguish a ripe, red cherry from a green leaf.

What is Spectrum Analysis ?

The colors produced by the prism are not only

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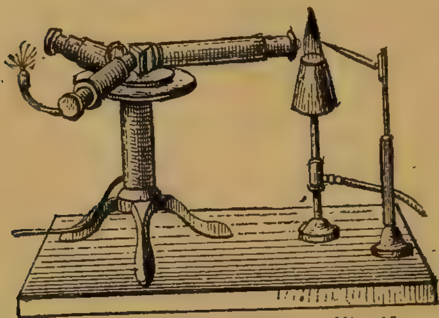
*From the Greek, A NEGATIVE and CHROMA color.

pure and elementary, but it has been found that the incandescent vapor of every substance, reveals through that medium a color or combination of colors *peculiar to itself.* Spectrum analysis, therefore, is the analytical examination of light from any source by means of a prism, or system of prisms, arranged in an instrument called the spectroscope.

How many kinds of Spectroscopes are there?

There are two; the *compound* and the *direct-vision* Spectroscope.

What is the Simple or Direct-vision Spectroscope?



Compound Spectroscope. Fig. 15.

In this instrument, the slit, admitting the light, the prism and lens and telescope for refining and viewing the spectrum, are all arranged in the same straight tube. This is sometimes made so minute that it can be carried in the pocket.

What is the Compound Spectroscope?

This splendid triumph of mechanical and scientific skill is composed mainly of four parts:

1st. A tube containing a lens, and the knife-edged slit for admitting the light. The lens refracts the light parallel upon the prism.

2d. A telescope by which the spectrum is viewed.

3d. A tube containing a lens for refracting the image of a measuring scale near to, and parallel

with the spectrum, in order to estimate the width of the lines and their intervals.

4th. The prism or prisms, in the centre of the arrangement, by which the light is refracted, and sometimes re-refracted. See Fig. 15.

What are the Spectral Lines?*

Newton, in his experiments on light, used a *round* hole for its admission, which was sufficient for his great discovery of the decomposition of light. In 1802 Wollaston substituted a *slit* for the round orifice, and now a new era dawns upon the science of Optics, for this slit revealed the fact that the solar spectrum is not pure, but is crossed in many points by dark lines. Here the matter rested for twelve years longer and was forgotten.

Who next took up the investigation?

In 1814, a German optician, named Fraunhofer, made experiments on light, using the Englishman's slit to form his spectrum, and added a telescope for the purpose of viewing it. At that moment, new and curious facts in the spectrum dawned upon the vision of Fraunhofer. He counted 590 of these dark lines between the red and the violet, and found that they varied in width and were unequally distributed in groups along the spectrum. What do these lines mean? That was the problem. Fraunhofer rightly conjectured what they are, but died before its verification.

What was Fraunhofer's Conjecture?

He believed that the cause of the dark spec-

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* It is a curious fact that for 127 years, the progress of knowledge, as respects the capabilities of the prism in the analysis of light, was held in check, for the simple reason of the difference between a SMALL ROUND HOLE AND A SLIT.

tral lines exists in the sun. What had become of the missing rays?

What was the next important step towards the solution of the problem?

In 1842, Dr. Draper added to the spectroscope used by Fraunhofer, a photographic plate of very sensitive surface, by which he nearly doubled the number of lines seen by the German, and experimented for the first time on the spectra of incandescent, familiar solids and gases. He discovered that the spectra of incandescent solids are without lines of any kind, while those of gaseous bodies, were known to be striped and broken with bright lines, and each with its own peculiar line or lines. The vapor of potassium gave three; two red, at one extremity of the spectrum, and one purple at the other. Sodium gave bright yellow lines, while iron exhibited several hundred such lines peculiar to itself. Oxygen, hydrogen, and nitrogen had, also a spectrum distinctive for each. What do these bright lines mean? Are they in any way connected with the dark lines of Fraunhofer? Thus the problem seemed more complicated, yet really near its solution.

Who next took it up and unraveled the mystery?

This was done by Kirchhoff (Keerkhoff) in 1859. He was engaged in mapping the bright lines of some of the metals; and in order to effect this more conveniently, he had placed Fraunhofer's spectrum over another that its dark lines might guide him. And now a revelation came to Kirchhoff, which solved the problem of the dark lines, and gave to Chemistry the most refined method of analysis yet discovered.

There stood sixty of the characteristic bright lines of iron, exactly coincident with as many of the dark, in position, width and grouping. What does this mean? Philosophy could give but one answer. The equation of chances showed that there were a pentillion of chances to one, that it was not accidental, but a result in the sphere of cause and effect. What is that cause? The old German's conjecture had been realized, and there was but one step more.

How did Kirchhoff demonstrate the causal relation of the bright and dark lines?

He and others showed by experiment that these lines are REVERSIBLE; that the bright lines of any gaseous substance, such as sodium, when it passes through its own vapor, before being refracted, are replaced by coincident dark lines in their spectra. That the rays from incandescent thallium vapor, are intercepted by thallium vapor, those from lithium vapor, by lithium vapor, and so of other metals.

On what principle or Law, then, did Kirchhoff base his explanation of the Lines of Fraunhofer?

Upon this law. *That every substance is especially opaque to such rays as it can itself emit when made incandescent.*

The same law may be thus stated in the language of the "undulatory theory;" waves of ether are absorbed with special energy, or their motion is taken up with special ease, by atoms whose periods of vibration synchronize with the periods of the waves.

How is this principle illustrated in Acoustics?

When a musical string is tuned to a certain note, if that note be sounded, the string will

sound in unison. That is, it readily absorbs what it was toned to emit, or it takes up with ease the motion with which its own molecular motions synchronize.

How is it illustrated by Radiant Heat?

It is a well known principle that a body radiates heat in the proportion that it absorbs heat. A good radiator is a good absorber.

What is the special application of the principle?

For example incandescent sodium vapor emits a bright yellow band; therefore, sodium vapor readily absorbs yellow, by the principle. Incandescent, potassium vapor emits red and purple, hence potassium vapor easily absorbs those colors.

What is, now, the necessary inference, which elevates us, at once, into Solar Physics?

It follows irresistably, that the dark lines of Fraunhofer, represent, each line or each system of lines, that substance in the sun's photosphere, whose incandescent vapor there has stripped it, by absorption, of its characteristic color before its prismatic refraction here.

"Let the light from the sun, and the light from incandescent sodium vapor, pass side by side through the same slit, and be decomposed by the same prism. The solar light will produce its spectrum, and the sodium light its yellow band. This yellow band will coincide exactly in position with a characteristic dark band of the solar spectrum, which Fraunhofer marked with the letter D.

Were the solar nucleus absent, and did the vaporous photosphere alone emit light, the dark line D, would be a bright one. Its character

and position prove it to be the light emitted by sodium. This metal, therefore, is contained in the sun."*

What other Metals were discovered by the same process, in the Sun's Atmosphere?

The metals calcium, barium, magnesium, iron, chromium, nickel, copper, zinc, strontium, cadmium, cobalt, rubidium, manganese and aluminum. Hydrogen is also there, but no ozone, nitrogen nor carbon.†

What effect had the explanation of Fraunhofer's lines upon our knowledge of the Sun?

It introduced a new theory of its constitution, that it consists of a solid or molten central nucleus intensely incandescent, and inveloped in a gaseous photosphere, whose vapors absorb the rays, which they themselves emit. Hence the lines of Fraunhofer.

Who soon after extended the Spectrum Analysis to the light of the stars, planets and nebulæ?

This was done by Alex. Huggins, and now we have not only Solar but Planetary, Stella and Nebular Physics.

What does it teach of the Planets?

It teaches us that light there, is the same as the light of the sun; that it loses nothing by its passage through space, has its dark heat and chemical rays as well; that the moon has no atmosphere and that the constituents of the planets are quite similar to each other and to those of the sun.

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* Tyndall on Light.

† How much more convincing is Kirchhoff's reasoning, when this coincidence of bands was seen in the case of the above metals having many bright bands; as nickle having 33; calcium 75; manganese 57 and iron at least 470.

What does it tell of the Fixed Stars?

That light there is still the same in its constitution and phenomena; that the unity of the universe is unbroken, for in the star Aldebaran, are found hydrogen, sodium, bismuth, antimony, mercury, iron, calcium and magnesium. Hydrogen has been discovered in so many hundred of the fixed stars that it may be regarded as the universal element.

What does it reveal of the constitution of the Nebulæ?

It reveals the fact that many of the nebulæ are gaseous, as they were long supposed to be, since the spectra of many of them, give only the *bright bands* of known elements. Hydrogen and nitrogen are there.

What facts indicate the delicacy of the Spectrum Analysis?

It will detect the presence of $\frac{1}{180000000}$* of a grain of sodium, $\frac{1}{6000000}$ of a grain of lithium, and the .001 part of a grain of the coloring matter in a blood stain.

What new Elements has it revealed?

It has added to Physics four new elements, viz., caesium, rubidium, thallium and indium.

What are the practical Uses of this Analysis?

It is invaluable to the Bessemer steel-making process, for the spectroscope indicates the exact moment in the spectrum, when carbon disappears from the converter. It promises to be of precious value in many chemico-legal cases, indicating the .001 of a grain of blood in a stain made more than a half century before. It will detect the most delicate physiological changes in the animal system, and discriminate readily

* Roscoe.

between wines of a new or old vintage These are only a few of the achievements of this wonderful process, and it is yet but in the infancy of its applications and developement.

Under what condition, alone, will substances yield their characteristic bands in the spectroscope?

In the condition, only, of an *incandescent vapor.* This vapor does not form a continuous spectrum, that is, the colors do not gradually fade into each other, but by an increased power of different refrangibilities, are grouped into distinct, colored bands. These spectra, then, consist of a series of colored lines, single or grouped, with intervals of darkness.

INTERFERENCE OF LIGHT.

What is meant by Interference of Light?

When light from different sources passes through the same tract of ether, the different waves set in motion, must affect each other. This is *interference of light*, when the effect of one is modified by that of the other.

In the motion of waves, do particles of matter progress, or mere motion?

As in the case of a bird upon the water, the waves progress, but not the bird; he only oscilates up and down.

What is the extent of this Interference and what is it like?

If the crest of one wave correspond with that of another, the effect is increased; but if crest correspond with sinus or depression, light is annihilated and darkness results. It is like sound and heat motion; add sound to sound SILENCE is often the result; add heat to heat, and the effect may be COLD.

DOUBLE REFRACTION.

What is Double Refraction?

It is the result which follows the splitting of a ray of light into two, the one rapid and the other slow, as it passes through certain substances.

What is the cause of Double Refraction?

It is the consequence of a peculiar arrangement of the molecules in certain bodies, which causes them to possess DIFFERENT DEGREES OF ELASTICTY IN DIFFERENT DIRECTIONS. As Iceland spar, or crystalized lime carbonate; rock-crystal and tourmaline.

As respect Refraction, how do all crystals divide themselves?

Into two classes:

First—Single refracting crystals, as rock-salt, alum and fluorspar.

Second—Double refracting crystals, as Iceland spar, rock-crystal and tourmaline, which have but one optical axis, and arragonite, felspar, crystalized sugar, mica, heavy spar, sulphate of lime and topaz, which have two axes.

Polarization of Light.—Polarization by Reflection.

What is meant by the Polarization of Light?

It is that peculir condition, which a ray of light acquires, after being reflected at a certain angle, from familiar polished surfaces, such as water, glass, etc.

Why is it termed a Po'ar condition?

Because Newton, who first saw it by refraction in Iceland spar, said that the beam of light had

acquired, by its passage, *sides;* and compared this two-sidedness of the beam to the two-endedness of a magnet. Hence the polarity of light.

POLARIZATION BY REFRACTION.

What is Polarization by Refraction?

It is the same peculiar condition, which a beam of light acquires, on passing obliquely *through* crystals and plates of glass.

How is the Polarization of Light accounted for?

An ordinary beam of light is the vibration of the ether in all directions *perpendicular to the line of its motion.* But, after certain reflections or refractions, these vibrations take place in a *single plain only*, either vertical or horizontal; hence the altered reflections or refraction of the changed beam by the molecules.

Is Polarization confined to crystalized bodies?

All substances, whether organic or inorganic, whose atomic arrangement is such, as to impart to the ether vibrating in them, different elasticies in different directions, are capable of polarizing light.

Does not this principle supply an important auxiliary to chemical analysis?

It is used, in this way, in certain practical analyses of such bodies as cane and grape sugar, tartaric acid, oil of turpentine, albumen and uncrystallizable sugar.

How is this application explained?

It depends upon a discovery by Biot, to the effect that certain organic substances of a liquid or semi-liquid consistence, exhibit a property

of polarity, called CIRCULAR POLARIZATION. When placed between two prisms of peculiar structure, the rays are stopped or transmitted according as one of the prisms is related through a certain angle either to the right or to the left; and the extent of this rotation is in proportion to the concentration of the liquid and the thickness of the mass of it.

How are these indications designated?

One is termed *right-handed polarization*, and the other *left handed polarization.*

What is the Polariscope?

It is an instrument by which light is polarized and examined.

How is it constructed?

A refracting polariscope is made of prisms of Iceland spar, known as Nicol's prisms. This is the best instrument.

A reflecting polariscope is made of two plates of glass, one of which polarizes the light and the other examines it.

What are the Chemical Rays of Light?

Like heat rays, the chemical rays of light are invisible, and being more refrangible than any luminous rays, are situated in the solar spectrum above the violet rays.

Why are these rays called the Chemical rays of Light?

Because it can be shown, that they act chemically upon certain bodies, producing decomposition and combination.

Are these rays, of all in the solar spectrum, the most active in promoting vegetable growth?

It appears that they are not, for it has been proved that it is in the *yellow* ray, where there is no atinic or chemical force, that the decomposition of carbonic dioxide is most active.

How do Heat-rays, Light-rays and Chemical-rays differ from each other?

They differ as yellow differs from green, that is by wave length and intensity of vibration. They are all affected alike by interference and polarization.*

In what four forms does Light manifest its effects upon matter?

1st. It alters elementary matter and gives it allotropic forms.

2d. It powerfully induces chemical combination.

3d. It produces mechanical effects.

4th. It effects chemical decomposition and combination.

What Art has its basis in chemical decomposition and combination by Light?

The valuable art of Photography.

What is Photography?†

It is the art of painting by means of Light.

How does Light effect this?

It effects it chiefly through certain compounds of silver, which are exceedingly sensitive to the influence of light, becoming decomposed by it and *changed in co'or.*

What is Phosphorescence?

It is luminous motion of the molecules of certain substances, caused by the etherial undulations in the absence of the sun. This being most familiar in phosphorous, is called *phosphorescence.*

What is Fluorescence?

It is that kind of phosphorescence, in which

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* Youman.

† From the Greek, photos, light, and grapho to write or paint.

the chemical rays of the solar spectrum, become luminous in such substances as fluor spar and solution of sulphate of quinine.

Meteorology—Methods of Observation—Instruments.

What is Meteorology?

It is that branch of Physics, which considers all the natural phenomena, whether terrestrial or atmospheric, that depend upon the action of heat, light, electricity and magnetism.

What two important branches are embraced in this definition?

Climatology and a large part of Physical Geography.

What is the object of Meteorology?

Its objects is to determine the various and constantly changing influences of heat, light, electricity and magnetism in the atmosphere and on land and sea.

Is Medicine interested in the study of Meteorology?

Obviously it presents a field abounding with great and valuable results, both present and future for Medicine and Hygiene.

METEORLOGICAL TABLES.

What is a convenient form of a Weekly Meteorlogical Report?

The following table is sufficiently practical, and quite simple.

METEORLOGICAL RECORD.

Condensed from observations taken at the office of the STATE BOARD OF HEALTH, State Capitol, Atlanta, Georgia, for the week ending —— ——, 1886.

DAYS.	Day of Month.	Temp. Degrees F. Highest.	Lowest.	Average.	Barometer* Average Height.	Rain Fall in Inches.	Ozone. Day.	Night.
Monday	7	82	68	$71\frac{2}{3}$	28.846	.14	5	4
Tuesday	8	85	65	$78\frac{1}{3}$	28.924	......	3	3
Wednesday	9	85	65	$77\frac{1}{3}$	28.965	......	2	4
Thursday	10	82	70	$75\frac{2}{3}$	28.846	.25	6	3
Friday	11	89	60	$76\frac{1}{3}$	28.677	.07	4	4
Saturday	12	90	65	$76\frac{2}{3}$	28.933	......	5	4
Sunday	13	92	71	$76\frac{1}{3}$	28.953	......	4	5
Week	...	92	65	76.48	28.878	.46	4.1	3.9

*Corrected for temperature.

Range for the week: Temperature, 12°; barometer, .516 in.; ozone, $3\frac{1}{2}$.

Fogs on the night of the 21st. Ozone deficient most of the week.

This table condensed with the addition of two or three heads of observation, constitutes a tabular report for the month. It may contain some twelve primary heads or columns.

First—Days of the month.

Second—Thermometer in open air—mean of weekly readings.

Third—Psychrometer—mean of wet and dry bulbs.

Fourth—Pressure of vapor in inches taken from elastic tension table according to barometer.

Fifth—Relative Humidity or per cent of saturation.

Sixth—Absolute Humidity or grains of vapor in cubic foot of air.

Seventh—Readings of Barometer and Thermometer attached reduced to freezing point.

Eighth—Clouds.

Ninth—Winds.

Tenth—Ozone.

Eleventh—Registering Thermometers—Maximum and Minimum.

Twelfth—Rain and Snow—Beginning of rain and snow—Ending of same—Inches of Rain and Melted Snow—Depth of Snow.

The above heads can be easily put in tabular form by the student.

What is the simplest method of ascertaining the amount of precipi a'ion of atmospheric moisture?

The simplest form of a rain-guage is a cylindrical vessel, it may be of tin, five or six inches deep, having vertical sides. This is exposed freely and just so near to the surface* of the ground, that no water may run into it, in each rain storm, and the water caught, afterwards measured in cubic inches.

What is the construction of the Rain-Guage or Udometer?

It may consist of a cubical box of tin or zinc, exactly ten inches in each side, open above. At an inch below its edge, it receives a funnel, sloping to a small hole in the centre. To the top of one of the edges, communicating with the interior, is soldered a short pipe, fitted with a stopple. This completes the instrument, which should be well painted.

This gauge is freely exposed, as before, and the water, caught afterwards, measured in a cylindrical glass vessel, graduated to cubic inches and the tenths of cubic inches.

Hence, one inch in depth, of rain in the gauge, equal to 100 cubic inches, will fill 100 inches of the graduated vessel; and one inch of the same vessel will indicate 1.100 of a cubic inch of rain.

The 1-10 of the graduated vessel will, of course, indicate the 1-1000 of a cubic inch.

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* The quantity of water caught depends, in part, upon the height at which the gauge is placed.

Does the amount of Humidity in the atmosphere, depend upon the quantity precipitated in rain?

Not at all; it may be less where there is a large rain-fall than in other places, where there is little rain.

Upon what does atmospheric humidity depend?

In any locality, it depends upon the presence of large areas of undrained, saturated lands, wide-spread swamps, lagoons, marshes and dense forests. The more a country is cleared and drained, the dryer and healthier it becomes.

Is it important, in a sanitary point of view, that the amount of humidity in the atmosphere should be ascertained?

This is a question of the first importance to the people of any locality or country—far more important than an inquiry as to the presence of carbonic dioxide or carbonic oxide. A good hygrometer should be in as frequent use in a dwelling, as the ever present thermometer.

How is the amount of water in any fall of snow ascertained?

A column of snow is caught in a cylinder, as so much rain, and after being melted, measured as before, as so much rain. Ten inches of snow, usually make one of rain.

When are observations made for the average of Cloudiness?

At 7 A.M., 2 P.M. and 9 P.M., daily. The average per cent. of cloudiness is given for each month.

How is this ascertained?

For a per cent. estimate, of course, 100 must represent entire cloudiness; 50, that half the sky is covered with clouds; 0, that the sky is perfectly clear, and the intermediate numbers the intermediate per cent. of cloudiness.

When are observations made for Rain and Snow?

The same hours which are used for observations on cloudiness, and a like average found for days and months.

When are observations made for Atmospheric Pressure?

At the same hours, and the average readings of the barometer are taken as before.

What remarkable fact, vouched for by the Smithsonian Institute, indicates the great importance of Barometric observations in Health Reports?

In extreme cases the change of atmospheric pressure amounts to nearly one pound per sq. inch of surface. If then 2,000 sq. inches represent the body of a man of average size, there may be in an hour, a difference of atmospheric pressure upon it, of some 2,000 lbs. According to Dalton, the superficies of the lungs amount to 201600 sq. inches; so that upon body and lungs, together, this difference of pressure may reach 203600 sq. inches or more than 101 tons.

Can these changes take place, without corresponding, great and serious changes in the physiological conditions of all who may be exposed to them? If the barometer be rising, this must greatly increase the labor of the heart, and tension of the large arteries; if falling, it must produce serious disturbance in the nervous and vascular systems.

When are observations made for Ozone?

At the same hours, 7 A.M., 2 P.M. and 9 P.M. An average is then taken according to a scale of ten degrees of coloration.

By what means are the observations on Ozone taken?

By means of Schonbein's test-paper, a strip of which is exposed at the hours designated. After exposure, it is compared wi h the given scale of ten degrees of co!oration. See Ozone Scale.

How are Schonbien's Test-Papers prepared?

Schonbein's test consists of s'rips of paper moistened with a dilute solution of potassium iodide and starch.

How is this last explained?

Ozone decomposes the iodide, setting the iodine free, which combining with the starch, strikes a deep blue color. Having, now, a standard of ten degrees of different shades of this characteristic blue, it is easy, by comparison, to find an average of the daily, monthly, and annual observations.*

Temperature.—Placing of Thermometer.

How should the open-air Thermometer be placed?

1st. It should be so placed as not to be affected by the direct rays of the sun or any heated body.

2d. It should be suspended on the North side of some thin wall, from a bracket some six inches from the wall.

3d. It should not be exposed to the open face of the sky. This causes it to give too low a temperature.

The mean temperature is obtained by taking the sum of the three *observations and dividing it bg three.*

Barometer.—Atmospheric Pressure.

How should the Barometer be placed, and observed?

1st. It should be suspended in-doors, in a room of uniform temperature.

2d. It should have a gcod light, but no exposure to the direct rays of the sun.

* The test-papers must be kept in closed bottles in a dark closet.

3d. Its position should be exactly vertical.

To observe it—

1st. Note the temperature of the attached thermometer; the heat of the body may affect this.

2d. Adjust the cistern, by causing the mercury just to touch the ivory point.

3d. Gently tap the case to loosen the adhesion of the mercury to the tube.

4th. Enter in their proper columns, both the reading of the barometer and *that of the attached thermometer.*

Humidity of the Atmosphere.—Hygrometers.

What is absolute Humidity?

It is the number of grains or grams of vapor contained in a definite portion, as a cubic foot, of vapor.

What is relative Humidity?

It is the ratio of the quantity of vapor contained in the air, to the quantity it could contain, at the observed temperature, if fully saturated.

How is absolute Humidity ascertained?

It is conveniently ascertained from tables, and on page 27 is given Daniell's Table, abridged from his Meteorlogical Essays, which shows absolute humidity for temperature, Fa. in English measure. Here, for the sake of increased accuracy, and variety, we add a more elaborate one, calculated in metric values.

Weight of one Cubic Centimeter of Atmospheric Air, in Grams, at Different Temperatures for every 5 degrees from 0 to 50° C. at 760 mm, and for every 9 degrees from 32° to 122 F.

			Difference.
0° C.	32° F.	0.001293	
5	41	0 001270	23
10	50	0.001248	22
15	59	0.001226	22
20	68	0.001205	21
25	77	0 001185	20
30	86	0 001165	20
35	95	0.001146	19
40	104	0 001128	18
45	113	0.001111	17
50	122	0.001094	17

How may this table be practically applied?

Example—What is the absolute weight of 1 cub. c.m. of air at 40°C? this being the temperature of observation?

Weight of 1 c.c.m. at 40° = 0·001128—Ans.

What is the weight of 1 c.c.m. of air for 42°?

Weight of 1 c.c.m at 45° = 0.001111
Differ. between 40° and 45° = 17
Add 3-5 of 17 to 0.001111 = 0.001111 + 10 = 0.001120—Ans. for 42°.

By the column of differences, we are enabled to calculate the intermediate values. If the questions had been asked in Farenheit, the interpolation of difference would have been 9ths instead of 5ths.

Record the results of these three daily barometric observations in their proper columns, and at the end of each month take their sum and average.

How is Relative Humidity ascertained?

Relative humidity is expressed in hundreths or per cents., full saturation being equal to 100.

It is easily calculated from the indications of dew-point instruments. And as in absolute weight, tables have been prepared which greatly facilitate the work.

These observations merit special attention. The Monthly Register of Meteorlogical Observations of the State Board of Health of Michigan, justly remarks; "The amount of moisture in the air is a matter of great importance, both in a meteorlogical and in a sanitary point of view."

What is the object of Dew point Instruments?

"The object of every dew point instrument," says Dr. Guyot: "Is to ascertain, by causing a part of the apparatus to cool, the temperature, at which the vapor contained in the air begins to condense, in the shape of light dew on the cooled portion of the instrument."*

If the temperature of the Dew point be known, may not all the hygrometrical conditions of the air be easily deduced from it?

They may. The Absolute Humidity, or the total amount of vapor in the atmosphere, is expressed by the number, in the tables of elastic forces of vapor, already given, due to that temperature.

The Relative Humidity, or the degree of moisture, being the ratio of the quantity of vapor actually contained in the air, to the quantity it could contain, if fully saturated, is expressed by the proportion.

*Dr. Guyot prepared, before the recent war, for the Smithsonian Institute, a collection of Tables, Meteorlogical and Physical, which culled from the ablest scientific sources in this country and Europe, embodies all that is most reliable and practical on the subjects presented. These tables, methods and formulæ are the basis of observations in all the signal stations of the Union.

Maximum Force of Vapor: Force of Vapor at Dew-point : : 1 : Relative Humidity.

Calling the Force of Vapor at the Temperature of the Dew-point, f.

Force of Vápor at the Temperature of the Air, F; the proportion becomes, F : f : : 1 : hence Relative Humidity $= \frac{f}{F}$

This formula gives the rule: *Divide the force of vapor, as given in the Table of Elastic Forces, corresponding to the temperature of the dew point, by the maximum of the force of vapor, due, in the same table, to the temperature of the air at the time of the observation.*

But since RELATIVE humidity is the object of inquiry, F* must be always greater than *f*. Hence relative humidity is expressed by a fraction, termed the *fraction of saturation.* Perfect saturation being represented by 100, in order to obtain this fraction in hundredths, the formula must be written: Relative Humidity$= \frac{f \times 100}{F}$

How is this Formula or Rule practically applied?

Example—Temperature of Air or t = 62°F.

Temperature of Dew-Point or ṭ = 53°F.

Number in Table of Elastic Force, corresponding to 62°F. = 580. (See page 27.)

Number corresponding in same table to 53° = 420.

We have interpolated for difference, at sight, 20, in each number, this being sufficiently accurate.

By the formula then; 420x100 ÷ 580 = 72 4. Ans.

All that is necessary, therefore, for these ob-

*F is always necessarily greater than f when the air is not saturated.

servations, is to find the temperature of the dew-point from Daniell's hygrometer or the wet and dry thermometers, also the temperature of the air from the dry bulb thermometer, and having obtained their respective tensions from the table of Elastic Forces, substitute those numbers in their proper places in the given formula.*

What is the most convenient instrument to be used in this observation?

The humidity of the air is easiest measured by means of the *wet bulb and dry bulb* thermometers; and these being quite sensitive, and combined in one instrument, is called the Psychrometer, from the Greek *psukros*, cold, and *metron*, measure. The tables calculated for its readings are known as Psychrometrical Tables.

How should this instrument be placed for observation?

The Psychrometer should be so placed, as to be freely exposed to the air, observing all the precautions given in connection with the Thermometer in the open air. The covering of the wet bulb, should be renewed often enough to secure cleanliness. A syringe will generally purify it without its removal. Rain water, only, should be used with this instrument. The covering should be wet, at least, fifteen minutes before each observation, unless it is covered with ice, for evaporation goes on from the solid as well as from the liquid state. If the temperature be at or below the freezing point, the thermometer will *mark* 32° *till all the water is frozen*†

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* Table VIII, page 75 of Guyot's Smithsonian Report, saves all trouble of calculation in these observations; but this table and others in the same work, are too extensive for our space.

† See directions in Monthly Register of State Board of Health, of Michigan. The annual reports of this Board reflect distinguished honor upon their government and people. When will the Legislature of Georgia, vindicate by a similar institution, the wisdom and intelligence of her people?

Why is it important to make observations on Ozone ?

"Observations on ozone are desired, as one element of climate, but especially to ascertain its relations to health and disease. Observers are requested to notice and record any apparent connection which the abundance or deficiency of ozone may have with the prevalence or absence of any given diseases, or its modification of their types."*

What casual Phenomena is it important to note ?

Thunder Storms, Tornadoes, Earthquakes.	Time of occurrence and direction of motion, width, and direction of path, effects produced, whether attended by electricity or hail and size of hail.

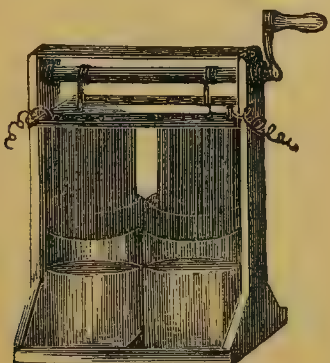
Meteors and Shooting Stars, their direction and time of occurrence

Aurora Borealis, its time of occurrence and disappearance.

Earthquakes, time of occurrence, direction of impulse, number of shocks and effects.

Note all unusual phenomena.

*Michigan Monthly Register of Health Reports.



Battery.

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